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The impact on freight transport

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by

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Executive Summary in Danish

I 2020 påbegyndte Vejdirektoratet arbejdet på en opdateret VVM-analyse for en 3. Limfjordsforbindelse ved Aalborg, hvilket inkluderede en cost-benefit-analyse af de trafikale aspekter af en ny Limfjordsforbindelse. Igennem diskussionerne omkring en ny Limfjordsforbindelse har pålidelighed, også omtalt som forsyningssikkerhed, været et tilbagevendende emne. Argumentet har været, at den nuværende infrastruktur over Limfjorden er upålidelig, for hvis Limfjordstunellen er spærret, kan Limfjordsbroen i Aalborg centrum ikke bære trafikken over fjorden uden at der opstår signifikante forsinkelser. En 3. Limfjordsforbindelse anses derfor som en løsning på dette pålidelighedsproblem.

I Vejdirektoratets arbejde med cost-benefit-analyser af ny infrastruktur regnes der på omkostninger af forsinkelser, der opstår som følge af mangel på kapacitet i vejnettet. Forsinkelser, der opstår som følge af trafikale hændelser såsom trafikuheld, er ikke medtaget i beregningerne. Det er imidlertid klart, at sådanne hændelser medfører signifikante forsinkelser i Limfjordstunellen når de forekommer såvel for persontransport som for godstransport. Målet med dette forskningsprojekt er derfor at belyse hvilke konsekvenser sådanne forsinkelser har for godstransport på kritisk infrastruktur og hvilke økonomiske omkostninger dette medfører.

Kritisk infrastruktur defineres i denne sammenhæng som infrastruktur, hvor der ikke eksisterer en alternativ rute som kan bære trafikken uden at der opstår signifikante forsinkelser, hvis den kritiske infrastruktur er spærret. Limfjordstunellen er således et eksempel på en kritisk infrastruktur. Analysen viser videre, at de konsekvenser der opstår i godstransport omkring Limfjordstunellen ved disse trafikale hændelser er de samme, som opstår på kritisk infrastruktur andre steder i Danmark, f.eks. på E45 ved Aarhus, E45 ved Hedensted, E45 ved Vejlefjordbroen, E20 på Østfyn eller på E20 ved Køge Bugt.

Der har i de seneste år været et stigende fokus på omkostningerne ved rejsetid og omkostningerne ved upålidelighed i godstransport i den videnskabelige litteratur. Det er dog stadig et emne i sin spæde begyndelse, og der er stadig lang vej endnu før omkostningerne kan estimeres præcist og modelleres. Der er derfor behov for forskning, der belyser hvilke dynamikker der opstår i godstransport ved forsinkelser ved trafikale hændelser såsom trafikuheld. Dette projekt tager et skridt i denne retning og gennem et studie af fem logistikvirksomheder, der opererer i og omkring Limfjordstunellen, belyses det, hvordan hændelser som trafikuheld påvirker godstransporten og omkostningerne herved.

Der bør i forhold til forsinkelser skelnes mellem to typer af forsinkelser, der har forskellige konsekvenser for logistikvirksomhederne. Den ene type er de forsinkelser der opstår ved den daglige trængsel i myldretiden om morgen og aften. Denne type trængsel er forudsigelige trængsel. Disponenter og chaufførerer i logistikvirksomheder ved erfaringsmæssigt at der på bestemte strækninger, f.eks. igennem Limfjordstunellen, opstår trængsel på bestemte tidspunkter. Denne forudsigelige trængsel håndteres ved, at der tillægges ekstra tid til de planlagte ture på disse strækninger. Den anden type forsinkelser er uforudsigelige forsinkelser, trafikale hændelser såsom trafikuheld, og det er denne type trængsel, der er fokus i dette forskningsprojekt. Det er ikke muligt for

logistikvirksomhederne at indlægge buffere på alle ture for at kunne håndtere forsinkelser som følge af uforudsigelige hændelser, og derfor er tilgangen i stedet, at når de opstår, så må planer ændres og det har en række konsekvenser for godstransporten, som analysen belyser i detaljer. De vigtigste resultater er:

1: Risikoen for at opleve forsinkelser får logistikvirksomheder til at investere
Analysen viser, at logistikvirksomheder investerer for at minimere risikoen for at blive forsinket af hændelser på vejen. Eksempler herpå er: Investering i fremskudte parkeringspladser og terminaler i de større danske byer for at minimere behovet for at køre i morgentrafik og dermed risikoen for at blive forsinket, hvis der opstår hændelser i denne morgentrafik. Investering i lyddæmpede lastbiler, der kan bruges til natlevering for at kunne levere om natten og dermed undgå kørsel i morgentrafikken. Investering i ekstra lastbiler og trailere for at kunne håndtere konsekvenserne af hændelser. Analysen viser således, at hændelser på kritisk infrastruktur skaber omkostninger for logistikvirksomheder allerede før de indtræffer idet virksomhederne investerer for at undgå kørsel i tæt trafik morgen og aften. Det er her risikoen for hændelser såsom trafikuheld er høj og de potentielle forsinkelser som følge af hændelser også er mest alvorlige pga. trafikmængden.
Casestudiet viste i denne sammenhæng også, at omkostningerne ved hændelser i tunnellen potentielt påvirker virksomheders lokaliseringsvalg, men yderligere undersøgelser af denne dynamik er nødvendige for at belyse dette i flere detaljer.

2: Forsinkelser kan sprede sig i omfang nedstrøms i logistikoperationerne til at inkludere lastbiler og gods, der ikke befandt sig i nærheden af hændelsen
Analysen viser, at når en lastbil ankommer forsinket til en terminal, som følge af en trafikal hændelse, så bliver sorteringen af gods på terminalen også forsinket. Dermed kan forsinkelsen sprede sig til andre lastbiler og andet gods, som dermed kommer forsinket afsted fra terminalen. Således kan en forsinkelse sprede sig i logistikvirksomhedernes terminaloperationer fra terminal til terminal, således at gods og biler, der ikke engang har været i nærheden af den trafikale hændelse, forsinkes. Et eksempel på denne dominoeffekt er, at ét uheld på en motorvej på Sjælland skabte en forsinkelse for nogle af Danske Fragtmænds lastbiler, og denne forsinkelse spredte sig efterfølgende til alle Danske Fragtmænds 27 terminaler, der er fordelt over hele Danmark. Analysen viste også, at da terminaloperationerne i nogle tilfælde kører 24 timer i døgnet uden buffere, så kan forsinkelserne leve videre i terminaloperationerne i flere døgn og dermed påvirke godstransporterne.

Dette er et nyt og vigtigt resultat for indtil nu har litteraturen om omkostningerne ved forsinkelser kun haft fokus på de lastbiler og dermed det gods, som bliver forsinket på vejen ved hændelsen. Derfor er denne dynamik heller ikke medtaget i nuværende beregninger af omkostninger ved forsinkelser. Dette betyder at omkostningerne på nuværende tidspunkt undervurderes, idet dette studie viser, at det potentielt er en større mængde lastbiler og gods der forsinkes af trafikale hændelser såsom uheld, end de lastbiler og det gods der befinder sig på vejen ved hændelsen. Der er behov for yderligere forskning for at fastslå størrelsen af denne dynamik, dvs. hvad er den gennemsnitlige domino-effekt nedstrøms i logistikoperationerne hver gang én lastbil forsinkes. Når dette er fastlagt, kan de gennemsnitlige antal biler forsinket ved en hændelse, multipliceres med denne faktor for derved at skabe et mere retvisende billede af antallet af lastbiler berørt af hændelsen.

3: Forsinkelser kan vokse i tidsomfang nedstrøms i logistikoperationerne

Analysen viser, at en forsinkelse forårsaget af en trafikal hændelse kan vokse i tidsomfang nedstrøms i logistikoperationen. Årsagen hertil er køre- og hviletidsregler og afhængigheder i ruteplaner f.eks. ved færgeruter. Et eksempel på dette fra analysen ses i Vendelbo Speditions operation: Når chauffører kører nordpå igennem Limfjordstunellen mod Vendelbo Speditions terminal i Hjørring, bliver de nogle gange forsinket af trafikuheld ved Limfjordstunellen. Dette kan medføre at chaufføren løber tør for køretid, hvilket betyder at Vendelbo må sende en bil med en anden chauffør ned og hente lastbilen. Hvis chaufføren er løbet tør for køretid, sender Vendelbo en lastbilchauffør afsted i en almindelig bil, og så kan denne nye chauffør overtage lastbilen og køre den til terminalen på hans køretid, mens den strandede chauffør kan køre den almindelige bil hjem til terminalen. Hvis chaufføren, der sad fast i tunnelen, er løbet tør for rådighedstid må denne chauffør ikke køre mere, og så bliver Vendelbo Spedition nødt til at sende en bil med to chauffører afsted, én der kan køre lastbilen videre til terminalen, og én der kan køre den almindelig bil med den strandede chauffør tilbage til terminalen. Det sker hver uge at Vendelbo Spedition må hente chauffører hjem, der er løbet tør for køretid på vej op gennem Jylland, og firmaet har derfor pensionerede chauffører tilknyttet, som hjælper med denne opgave. Konsekvensen er, udover ekstra omkostninger til biler og chauffører, at forsinkelsen vokser i tid. Forsinkelsen er således ikke kun den tid lastbilen holder i kø ved trafikhændelsen, men det er også den tid, som det tager at få en ny chauffør frem til den strandede lastbil. Analysen viste også et andet eksempel på øget forsinkelse: Hvis en lastbil kommer forsinket til terminalen hos Vendelbo Spedition i Hjørring, der kører meget gods til Norge, så forsinker det også sorteringen og pakningen af gods til de afgående biler på terminalen, og det betyder nogle gange at de nordgående biler, der skal til Norge, ikke kan nå færgerne i Hirtshals om aftenen. Dermed bliver godset forsinket endnu mere til den efterfølgende dag.

En forsinkelse kan således vokse i tid nedstrøms i logistikoperationen. Dette er også et nyt resultat for indtil nu har litteraturen om omkostningerne ved forsinkelser taget udgangspunkt i den tid hændelsen tager på vejen. Dette betyder igen, at omkostningerne ved events undervurderes, og yderligere forskning er nødvendig for at fastslå størrelsen af denne dynamik, dvs. hvordan en forsinkelse i gennemsnit udvikler sig tidsmæssigt igennem en logistikoperation, og hvad relationen er mellem en given tidsudstrækning af en hændelse på vejen og den gennemsnitlige forsinkelse denne skaber i logistikoperationerne. Når dette er fastlagt, kan den tidsmæssige udstrækning af en given hændelse på vejen korrigeres med denne faktor for derved at skabe et mere retvisende billede af hvilken forsinkelse hændelsen skaber.

4: Lastbiler på veje omkring den kritiske infrastruktur bliver også forsinket af hændelser på den kritiske infrastruktur

Analyser af forsinkelser og omkostninger tager i dag udgangspunkt i de forsinkelser, der opstår på vejen, hvor hændelsen sker. Analyser af omkostninger ved hændelser i Limfjordstunellen er således baseret på analyser af hvor lang tid trafikken på E45 i og omkring Limfjordstunellen forsinkes som følge af hændelserne i Limfjordstunnellen. Analysen viste imidlertid, at lastbiler på omkringliggende veje også forsinkes som følge af hændelser i Limfjordstunellen.

Når en hændelse indtræffer i Limfjordstunellen i myldretiden sker der typisk det, at trafikken forsøger at komme over Limfjordsbroen i Aalborg centrum. Sker uheldet om eftermiddagen, hvor trafikken er størst nordpå, er konsekvensen derfor typisk, at trafikken i Aalborg Centrum går i stå pga. trængsel med massive forsinkelser til følge. Analysen af Danske Fragtmænds operation i Aalborg viste, at dette betyder, at de lastbiler der leverer og henter varer i Aalborg syd for fjorden, bliver forsinket selv om de hverken kører på E45 eller skal krydse fjorden. Når vejene i Aalborg er fyldt op med biler, der holder i kø for at komme over Limfjordsbroen, så bliver det sværere for Danske Fragtmænds lastbiler at komme rundt i byen, og så bliver de også forsinkede.

Analysen af Schulstads operation viste videre, at planlægningen og restriktioner på vejnettet omkring den kritiske infrastruktur kan presse flere lastbiler ud i myldretidstrafikken og dermed forværre omkostningerne for godstransporten ved forsinkelser. Schulstad leverer om natten i flere danske byer for at undgå kørsel i morgenmyldretiden, og dermed minimere risikoen for at blive fanget i trafikuheld, men pga. at Aalborg Kommune ikke tillader natlevering i samme omfang som nogle andre danske byer, er Schulstad nødt til at køre i morgenmyldretiden i Limfjordstunellen for at levere om morgenen inden butikkerne åbner i Aalborg.

Dette er endnu et nyt resultat og også i forhold til dette er implikationen igen, at på nuværende tidspunkt undervurderes konsekvenserne af hændelser for godstransporten idet der ikke har været fokus på forsinkelser på omkringliggende veje. Videre forskning er nødvendig for at fastlægge størrelsesordenen af disse forsinkelser.

5: Mere forskning er nødvendig før omkostningerne ved forsinkelser for godstransport ved hændelser som trafikuheld kan kvantificeres

Dette forskningsprojekt har kvalitativt identificeret hvordan hændelser på kritisk infrastruktur påvirker godstransport. Mere forskning er dog nødvendig før det er muligt at kvantificere omkostninger herved. Første skridt bør være dels at kvantificere de investeringer logistikvirksomheder laver for at undgå kørsel i myldretiden, dels at kvantificere hvordan forsinkelser affødt af hændelser vokser tidsmæssigt, hvor meget de spreder sig til andet gods, og hvordan hændelser på kritisk infrastruktur påvirker godstransport på omkringliggende veje. Når disse elementer er belyst, vil vi have et retvisende billede af hvor mange lastbiler og hvor meget gods en given hændelse på et stykke kritisk infrastruktur rent faktisk forsinker, og først når vi har dette, kan vi begynde at beregne omkostningerne ved forsinkelserne.

Dernæst kommer spørgsmålet om hvordan omkostningerne ved den forsinkede mængde lastbiler og gods kan fastsættes. Der er en række af omkostningerne for logistikvirksomheder, der er relativt nemme at fastsætte, f.eks. chaufføromkostninger, udstyrsomkostninger og terminalomkostninger. Andre omkostninger er mere vanskelige at fastsætte f.eks. tabt brand-value overfor kunden ved forsinket levering. Typen af gods har også stor betydning, såvel for forsinkelsernes betydning og for omkostninger i næste led i supply chain.

For nogle typer af gods er hurtig leverance afgørende, og et eksempel herpå er Vendelbo Speditions transporter af dele til olieindustrien. I sådanne transporter har Vendelbo Spedition nogle gange fløjet chauffører i position forskellige steder i Europa, så de kunne overtage lastbiler, der var blevet forsinket af trafik, for at holde transporten i bevægelse. Ligeledes har firmaet også haft transporter, der er startet med to chauffører i lastbilen imens en tredje chauffør er blevet fløjet i position, så den tredje chauffør kunne overtage lastbilen, når de to chauffører i lastbilen havde opbrugt deres køretid. I den modsatte ende af spektret er der typer af gods hvor forsinkelse ikke betyder noget. To eksempler herpå er fra Danske Fragtmænd i form af transport af vand og korn. Når der skal køres vand mellem to lagre, hvor der typisk allerede står 1.000 paller med vand på modtagerlageret, eller hvis der skal flyttes 10.000 tons korn mellem Sjælland og Jylland i løbet af en måned, så betyder en eller to timers forsinkelse intet for modtageren.

Det afgørende her er betydningen af rettidig levering nedstrøms i supply chain, og dette leder fokus til omkostninger ved stødpudelagre og produktionsstop. Der er behov for videre forskning, der kan kvantificere omkostninger ved transportforsinkelser indenfor forskellige industriers supply chains. Som eksempel fra analysen på, hvorfor dette led er afgørende for de samfundsøkonomiske konsekvenser, kan betydning af rettidig leverance af emballage til Arla Foods fabrik i Svenstrup fremhæves. Fabrikken får emballage leveret fra Fyn eller Frankrig, og det sker at disse transporter forsinkes af hændelser på E45 i Østjylland. Hvis transporterne forsinkes omkring 2 timer opbruges stødpudelageret og produktionen går i stå. Den tabte produktion kan ikke indhentes, da fabrikken kører i døgndrift, og afhængigt af produktet, der produceres den pågældende dag, er omkostningen af medarbejdere der ikke har noget at lave og mistet produktion mellem 50.000 og 100.000 kr. i timen. Fra januar til august i 2020 stod fabrikken stille i over en time ved tre lejligheder, som følge af forsinkede lastbiler med emballage. I dag er denne type omkostninger nedstrøms i produktionskæden hos modtageren af godset og derefter ikke medregnet i analyser af omkostninger ved forsinkelse af godstransport. En tre timers forsinkelse af en lastbil med emballage til Arlas fabrik vil derfor i dag i cost-benefit-analyser i Danmark blive fastsat til en værdi af tre timers forsinkelsestid for godstransport hvilket svarer til 2.394 kr. Omkostningen på mellem 50.000 og 100.000 kr., som Arla taber som følge af at stødpudelagret opbruges de første to timer og at produktionen derfor ligger stille den tredje time, medregnes ikke i cost-benefit-analysen. Igen er konklusionen, at omkostningerne ved forsinkelser som følge af hændelser undervurderes, da konsekvenserne hos modtageren af forsinket levering af gods ikke medregnes. Fremtidig forskning bør belyse hvordan disse omkostninger kan inddrages i analyserne.

6: I danske infrastrukturanalyser undervurderes de omkostninger som uforudsigelige hændelser medfører for godstransporten

Tilsammen betyder de fem effekter præsenteret ovenfor, at omkostningen for godstransport ved hændelser som trafikuheld på kritisk infrastruktur undervurderes, hvis der i analyser heraf udelukkende fokuseres på omkostningen for de specifikke lastbiler og dermed det gods, der bliver forsinket på vejen ved hændelsen. I analyser af infrastruktur i Danmark beregnes netop kun omkostningen for de biler, der bliver direkte forsinket ved den trafikale hændelse, og denne beregnes med udgangspunkt i længden af hændelsen. Det må derfor konkluderes, at de omkostninger, der opstår for godstransport som følge af trafikale hændelser på kritisk infrastruktur, undervurderes i danske

infrastrukturanalyser på nuværende tidspunkt. Dermed giver nuværende cost-benefit-analyser af nye infrastrukturprojekter ikke et fuldt billede af disse projekters økonomiske konsekvenser for godstransport.

I forhold til beregningerne omkring en 3. Limfjordsforbindelse betyder dette, at hvis en 3. Limfjords-forbindelse minimerer forsinkelserne ved uheld i den nuværende Limfjordstunnel, idet den nye for-bindelse vil kunne bære trafikken, hvis Limjordstunnellen er spærret pga. uheld og omvendt, så vil den nye forbindelse medføre en økonomisk besparelse for godstransport, som ikke er medregnet i cost-benefit-analysen for en 3. Limfjordsforbindelse.

1 Introduction

The starting point for this research is found in the 2020 VVM evaluation by the Danish Road Authority of a proposed new high-way connection across the Limfjord near Aalborg. As part of this work, a cost-benefit analysis is being calculated to show the costs and benefits arising in passenger and freight transport if a new connection across the Limfjord is built to supplement the current two connections, i.e., the Limfjord Tunnel east of Aalborg City center and the Limfjord Bridge in the center of Aalborg.

One aspect of the discussions around the benefits of a new Limfjord connection has been reliability. An argument, which has been raised in discussions of the benefits of a third connection, is the argument that the current Limfjord Tunnel is critical infrastructure in the sense, that if the tunnel is blocked due to an event such as an accident, then there are no alternatives. The Limfjord Bridge is not capable of carrying both the traffic normally carried by the bridge as well as the traffic carried by the Limfjord Tunnel without significant congestion and delays occurring. The argument therefore goes, that when events occur which blocks the Limfjord Tunnel, and this sometimes happens, it generates significant costs for passenger and freight transport. The argument is further, that if a new connection is built, then this will solve the problem because if one connection is blocked due to an event, then the other two connections will be able to carry the traffic between the northern and southern part of the region without significant congestion and delays.

Until now the Danish Road Directorate has focused on congestion arising due to lack of capacity in peak-hour traffic and the costs associated with this in the Danish Country Traffic Model (Landstrafikmodellen), which form the basis for cost-benefit calculations of infrastructure in Denmark. Events blocking traffic, such as accidents, snowstorms, floods etc., is not part of this model (The Danish Road Directorate 2020). However, it is clear that such events occur, and they do have a consequence for passenger and freight transport, and therefore the focus on this has been growing in the past years. The purpose of this research project is therefore to identify what consequences such events have for freight transport on critical infrastructure.

The research questions therefore are:

1) What impacts do events on critical infrastructure have on the daily operations of freight companies?
2) What is the economic cost for freight companies caused by these events?

Events in this perspective can be accidents, snowstorms, floods etc. that are not foreseeable. It is thus not the daily congestion delays that are in focus, it is the more severe events happening less often causing longer delays. Critical infrastructure is defined as infrastructure where no alternative infrastructure exist which can carry the traffic from the critical infrastructure in case of events blocking the critical infrastructure without significant congestion and delays.

The structure of the report is as follows. Chapter 2 presents the theoretical background for the study. Chapter 3 the methodology. Chapter 4 the case study and Chapter 5 the analysis and finally Chapter 6 presents the conclusion.

2 Theory

Research in travel time reliability (TTR) and value of reliability (VOR) have been growing topics in recent years. It is well known that travelers take TTR into account when planning journeys (de Jong, G. C., Bliemer 2015, Andersson, Berglund et al. 2017). If travel time is unreliable, travelers add more time to the journey, head-start, to be sure to arrive at the destination on time. This holds for personal travel and for freight transport.

As argued by (Andersson, Berglund et al. 2017) value of time (VOT) is often included in Cost Benefit Analysis (CBAs) but VOR is often overlooked. A good example of why reliability is a crucial component of CBAs is given by (de Jong, Gerard, Kouwenhoven et al. 2014), who argues that a reduction of speed limits may lead to increased travel times and thus increased costs, but this may be compensated by the benefits arising from increased reliability. As argued by (de Jong, Bliemer 2015) important user benefits may thus be discarded if VOR is not included in CBAs. The most likely reasons for the lack of VOR in CBAs is, as argued by (Andersson, Berglund et al. 2017), the lack of good estimates of VOR. The VOR for freight is complex to estimate, and the few studies that estimates VOR for freight transport have come to different results and are difficult to compare due to different methodologies (Andersson, Berglund et al. 2017). Attempts to transfer VOR estimates between countries have also failed due to the context dependent nature of VOR (Andersson, Berglund et al. 2017). The relationship between VOT and VOR is also complex as shown by (Tao, Zhu 2020) who shows that ignoring reliability will risk overestimating VOT.

One way of including the VOR in CBAs is to use a value related to the VOT. In Sweden the national transport planning authorities assumes the cost of delay to be twice the cost of ordinary travel time, but as argued by (Andersson, Berglund et al. 2017), there appears to be no scientific foundation or explicit reasoning behind this. In Denmark the cost of delays is assumed to be 1,4 times of the cost of ordinary travel time, and according to (The Danish Road Directorate 2020) this measure derives from earlier calculations at DTU (DTU 2021)

We thus face three issues: First, how to measure TTR, second, how to estimate the VOR, and third, how to include the VOR in transport models for use in CBAs.

Different studies have measured TTR in different ways (de Jong, Bliemer 2015), and as argued by (Andersson, Berglund et al. 2017) four main approaches have been used: Standard deviation, spread, share of delayed shipments and average delay, but no consensus have been reached in the literature on which measure to use. As argued by (Engelson, Fosgerau 2016) the choice of measure is crucial for the way in which extreme events are included. As an example, using the 80 percent quantile and median of travel time as measure, has the advantage of being fairly robust while other measures may be more sensitive to extreme travel times in the tail of the travel time distribution (Engelson, Fosgerau 2016). Another measure example is the buffer time index that expresses the buffer needed to be on time 95 percent of times, which is therefore defined by the difference between the mean travel time and the 95 percent quantile (Engelson, Fosgerau 2016). Yet another similar index is the planning time index defined as the 95 percent quantile divided by the free-flow travel time (Engelson, Fosgerau 2016).

As there is no consensus on how to measure VTT it hardly comes as a surprise that there is no consensus on how to estimate VOR either. As argued by (Engelson, Fosgerau 2016) different cost measures can be used, and the three central measures are: measured based on scheduling preferences rooted in the theory of scheduling behavior, Bernoulli measures which considers utility as a function of monetary amount, and measures that are defined directly in terms of statistics of the travel time distribution, for example the mean-standard deviation model (Engelson, Fosgerau 2016). The mean-standard deviation model is the one mostly used in practical application and in CBA (Engelson, Fosgerau 2016).

As mentioned, only few studies exist that estimates VOR and the results vary and are hard to compare (Andersson, Berglund et al. 2017). The largest study so far was done in the Netherlands to established VOT and VOR and relied on a stated preference study with more than 700 respondents consisting of shippers and carriers (de Jong, Kouwenhoven et al. 2014). Interestingly (de Jong, Kouwenhoven et al. 2014) found very limited VOR for shippers and mostly insignificant VOR for carriers. (de Jong, Kouwenhoven et al. 2014) argues that one explanation for this might be that the agents in the freight transport field thinks in transport time and not variability, and thus relies on buffers, i.e., buffer time, buffer stock, buffer staff and buffer equipment. It might have been that the respondents when answering the SP questionnaire only gave the direct impact of changes in variability and not included the impact of the cost of changes to the buffers (de Jong, Kouwenhoven et al. 2014). Jong et al. (2014) therefore argues that in-depth interviews with shippers and carriers are needed to understand the costs in detail.

(Andersson, Berglund et al. 2017) argues for a focus on four specific types of effects of delays. Firstly, Anderson et. al. (2017) argues for a distinction between direct effects and indirect effects. Direct effects are the longer transportation time, increase driver salary cost etc. The indirect effects are the effects on the system caused not by the delays but by the risk of delays (Andersson, Berglund et al. 2017). Actors in the transport field are used to delays and therefore plan accordingly and the indirect costs are the cost for the flexibility and backup that makes it possible to handle delays. As such the indirect costs are not caused by a specific delay, they are incurred before the delay occurs (Andersson, Berglund et al. 2017). Second, (Andersson, Berglund et al. 2017) distinguishes between four types of delays defined according to two dimensions: magnitude and frequency. Most delays are small and frequent, and therefore expected and planned for by the actors in the system by the use of safety stock or margins in timetables, and therefore the system can handle these delays with only minor consequences, and these are termed “Expected risks” (Andersson, Berglund et al. 2017). More severe events which happen more rarely are termed “Contingencies” and defined as “No plans, but often possible to manage. Medium consequences” (Andersson, Berglund et al. 2017, p.62). In relation to the magnitude events that occurs often and have large consequences are termed “System Killers” as no companies will be able to survive in such a system (Andersson, Berglund et al. 2017). Finally, events that are rare and have large consequences are called “Catastrophic events” defined as quote: “No plans and small possibilities to manage. Very large consequences” (Andersson, Berglund et al. 2017, p.62).

While system killers can be ignored and catastrophic events should be analyzed as individual case studies, the expected risks and the contingencies are highly relevant for studies of value of reliability (Andersson, Berglund et al. 2017). The challenge is, however, that more studies are needed to identify the costs emerging in expected risks and contingency situations (Andersson, Berglund et al. 2017). Some of the factors influencing the cost are linear, as argued by (Andersson, Berglund et al. 2017), for example salary cost, some are step wise, for example missed connections, and some are non-linear, for example disrupted operations (Andersson, Berglund et al. 2017). However, it is important that both the expected risks and the contingencies are included in the calculation of cost (Andersson, Berglund et al. 2017).

The distinction between expected delays and unexpected delays in the form of delays caused by accidents and bad weather is also used by (de Jong, G., Kouwenhoven et al. 2009), who argue that most attention is often given to arriving to late, but there are also other costs with unexpected delays, for example greater than expected decline in value of goods with perishable goods, missed connections of transshipment points, waiting time for staff at delivery points or missed delivery window and missed potential to appley just in time principles.

With no consensus on TTR measures, nor any consensus on how to estimate VOT, different incomparable results from the few studies that estimates VOT, and a need for more detailed studies to understand the details of the dynamics occurring in freight transport as a consequence of delays, the including of VOR in CBA is naturally in its very early phase.

(de Jong, Bliemer 2015) synthesizes different approaches to including VOR in transport models into three overall approaches. The first and currently most feasible approach presented by (de Jong, Bliemer 2015) is to keep the transport models as they are, and then include a post-processing module which handles the reliability and calculated the costs. In this approach the outcome of this module is not fed back into the model, i.e., it is a one-way process. In reality the drivers and decision makers in freight transport will take unreliability into account when choosing routes, which this approach does not. The advantage of the method is that it is relatively easy to apply in practice (de Jong, Bliemer 2015). In this approach unreliability is assumed to be a function of route travel times. Empirical studies suggest that a near-linear relationship exist between a route standard deviation and a route travel time divided by the route distance. This means that through empirical studies in a given country/region it is possible to establish the parameters for the linear relationship and assume that these are the same on all routes, and this can thus be combined with VOR values to calculate the costs of unreliability (de Jong, Bliemer 2015). However, (de Jong, Bliemer 2015) underscores that when fitting the function, it is important that extreme events such as accidents, snowstorms and floods are excluded from the dataset as these extreme events have a significant impact on the standard deviation. Relating this to the classification of delays presented by (Andersson, Berglund et al. 2017), this approach thus covers only expected risks.

Turning to more complex ways of modelling the cost of unreliability for CBAs (de Jong, Bliemer 2015) suggest to extent the first approach with a feedback-look from the unreliability module to the model, so that the agents take unreliability into account in mode and route choice. In this approach

it is also possible to use a set of scenarios covering traffic incidents, road work, day of week etc., and estimate regression models for the standard deviation for each scenario and use these scenarios in the model (de Jong, Bliemer 2015). Finally, the most advanced approach proposed by (de Jong, Bliemer 2015), which is not currently applicable in practice as more research is needed, is to use more advanced models for the delay type. Status today is that in some countries the simplest approach mentioned by (de Jong, Bliemer 2015) has started to become implemented in transport models and CBA models.

The purpose of this study is to identify what impacts events on critical infrastructure have on the daily operations of freight companies and what is the economic cost for freight companies caused by these events. As seen from the literature presented above, the literature on VOR is in its youth, and what is needed is a better understanding of the dynamics occurring in logistics companies when delays occur, and the costs associated with these dynamics. Further, in part of the literature events understood as accidents, snowstorms, floods etc., are excluded from the analysis, and focus is placed on the average delays. To use the terms defined by (Andersson, Berglund et al. 2017), we can say that the literature is just starting to build models that handles the expected risks. Contingency delays are still poorly understood and detailed studies are needed to explore the dynamics relating to these. Therefore, this study aims at filling this gap by analyzing in detail the dynamics that occur when freight transport is delayed by events such as accidents, snowstorm and floods on critical infrastructure.

3 Methodology

To answer the research question, a case study methodology was used (Flyvbjerg 2006). To illuminate the dynamics an information-based choice of case was made, and a paradigmatic case chosen (Flyvbjerg 2006).

There are several places in Denmark where we find infrastructure which is critical in the sense that there is no alternative route which can carry the capacity in cases of events blocking the route without significant delays occurring. The Limfjord Tunnel is chosen as the case in this project. The daily traffic through the Limfjord Tunnel in 2019, before the Covid19 pandemic, was around 89.000 vehicles. The daily traffic across the Limfjord Bridge was around 33.000 vehicles. In peak-hour traffic experience show, that if the tunnel is blocked, then the bridge is not capable of carrying the extra traffic load without significant delays and congestion in Aalborg city center (The Danish Road Directorate 2020). Therefore, the Limfjord Tunnel is a critical case in relation to the definition used.

The Limfjord Tunnels is assumed to be a paradigmatic case in the form that the dynamics seen on this critical infrastructure will probably be similar to the dynamics seen on other pieces of critical infrastructure in Denmark. The interviews conducted showed this assumption to be correct as several respondents compared the situation around the Limfjord Tunnel to the situation on other pieces of critical infrastructure in Denmark, such as the E45 highway by Aarhus, the E45 by Hedensted, the E45 highway by the Vejle Fjord Bridge, the E20 in the eastern part of Funen or the E20 highway by Køge Bugt.

To explore the dynamics that occur in the case of events for logistics companies operating trucks crossing the Limfjord Tunnel an explorative study based on semi-structured interviews as described by (Kvale 2004) was conducted in five logistics companies operating around and through the Limfjord Tunnel. Two 1st-party-logistics providers, one 2nd-party logistics provider and two 3rd-party logistics providers was chosen as case companies.

In all companies semi-structured interviews were conducted of key persons with a detailed knowledge of the logistics operation. Interview respondents from each company was chosen who had knowledge about the operation and the impact of events in the Limfjord Tunnel. Depending on the company size and structure, different positions were chosen in each company, to make sure that the respondent had the knowledge needed for the analysis.

Company: Arla Foods

Arla Foods was chosen as a 1PL case as Arla Foods operates a powder milk factory Akafa in Svenstrup located south of Aalborg. There is a significant transport of milk to this factory and a high share of these transports pass the Limfjord Tunnel in Arla Foods' own trucks. To gain knowledge of how events in the Limfjord Tunnel influence the operations by Arla Foods' Site Director Jonna Mortensen was interviewed.

Company: Lantmannen Schulstad A/S
Lantmannen Schulstad A/S produces and distributes bread to shops across Denmark on trucks owned and operated by Lantmannen Schulstad A/S. With one of three factories located in Pandrup north of the Limfjord Tunnel Lantmannen Schulstad A/S has a significant transport through the Limfjord Tunnel and was therefore chosen as a 1PL case. Lantmannen Schulstad A/S's Supply Chain Manager Niels Holm was interviewed.

Company: Aalborg Vognmandsforretning A/S (AVAS)
AVAS is a transport company located in Nørresundby which therefore have a significant number of trucks crossing the Limfjord Tunnel. AVAS was therefore chosen as a 2PL case and CEO Jan Ruberg Kjelgaard was interviewed.

Company: Vendelbo Spedition A/S
Vendelbo Spedition A/S is a 3PL located in Hjørring north of the Limfjord, with a significant number of trucks passing the Limfjord Tunnel. Vendelbo Spedition A/S was chosen as a 3PL case, and CEO Jesper Bundgaard Madsen was interviewed.

Company: Dansk Fragtmænd A/S
Danske Fragtmænd is one of the large 3PL's in Denmark which also have a significant number of transports through the Limfjord. Due to the organization of Danske Fragtmænd, four persons were interviewed: Danske Fragtmænd A/S CIO Ulf Preisler, Jørgen Kannik A/S CEO Jørgen Kannik, Danske Fragtmænd Transport A/S Division CEO Kenneth Jespersen and Danske Fragtmænd Transport A/S Chief Dispatcher Søren Køpke.

All interviews were transcribed and analyzed. The analysis is presented in the following way: Chapter 4 presents each company case with a focus on the logistics operation and how this is impacted by events in the Limfjord Tunnel specifically and in critical infrastructure in general. The cases are presented in detail because as mentioned in the previous chapter there is a need in the literature for studies illuminating the details of what happens when delays occur. Quotes from the respondent therefore play a key role in the presentations. When translated quotes can lose some of their meaning and therefore the original danish quote is always presented beneath the English translation. Each case was presented to the given company for approval to make sure no confidential information was disclosed. As the case study was conducted it became apparent that the dynamics seen in relation to events in the Limfjord Tunnel are comparable to the dynamics occurring when events occur on the other highways mentioned above. Scope was therefore expanded in the interviews to cover such events also to create a detailed understanding of the dynamics. The company cases are presented using detailed descriptions to illuminate the complexity in the ways in which the events influence the logistics operation. Chapter 5 thereafter analyzes the results from the case study, and chapter 6 presents the conclusion.

4 Case study

To understand how events in the tunnel influences freight transport let us start with Arla Foods.

4.1 Arla Foods transport to the Akafa factory

Arla Foods owns the Akafa factory in Svenstrup south of Aalborg, which produces powder milk. For this production the factory receives approximately 1.500.000 kg of milk every day during the week including Saturday and Sunday, and the factory works around the clock (Mortensen 2020). The milk is transported to the factory on milk trucks with a payload capacity of around 30.000 kg, which means that on average 50-60 milk trucks arrive on the factory every day. During the production of powder milk some residue products are generated, for example cream, which is transported to other Arla factories. On average the transport of these products generates approximately 10 truck trips from the factory. Finally, the powder-milk production is loaded on ordinary tractor-trailer trucks and transported south to customers in Europe, and the transport of this production generates around 15-20 truck trips per day. On top of this a number of trucks arrive each day with other types of supply for the production, for example packaging, which we shall return to later. For the collection of milk from farms to the factory and the transport of residue-products Arla owns its own trucks and employs drivers. Approximately 75 drivers are employed at the Akafa factory (Mortensen 2020).

The milk transported to the factory is collected from farms across Northern Jutland, however, the majority of the milk comes from farms located north of the Limfjord. Most of the milk from the southern part of Northland, i.e. south of the Limfjord, is transported to the Arla factory in Hobro, and milk from areas further south in Jutland is transported to the Rødkjærsbro factory (Mortensen 2020)

The logistics operation of Akafa is organized as follows: the milk-trucks typically drives around the clock, with driver-change at 4.00 in the morning and 16.00 in the afternoon. Drivers often work 12 hours shifts, and during a shift they typically do 2 trips, i.e. they drive out to the farms, fill the truck, return to the factory and unloads, and goes out to the farms and fill again, and return again. Some drivers do 3 small trips if the farms are located close to the factory, and likewise, if the farms are located in the distant areas of Northern Jutland and it is small farms and thus many stops during the trip, then the driver might only do one trip during his shift. When asked about what times during the day that was most critical the respondent answered:

> *"Respondent: …Det worst is probably in the afternoon where they have the afternoon-shift. The ones who take off in the morning are returning again in between morning and noon if they have 3 runs, and most of them only have 2 runs. It is only few who have 3 runs. But if it is 2 runs then they are here again between 10:00 and 14:00 o'clock and that is not the worst time. So, the worst time is actually the shift in the afternoon." (Mortensen, 2020)*

> *"Respondent: ...Det værste er nok her om eftermiddagen, hvor de har eftermiddagsskiftet. Dem som suser afsted om morgenen, de kommer hjem igen midt på formiddagen, hvis de har 3 ture, og de fleste af dem har næste kun 2. Der er kun nogle enkelte der har 3. Men hvis det så er 2 ture, så er de hjemme mellem kl. 10 og 12 og det er ikke lige det værste tidspunkt. Så det værste tidspunkt, det er egentligt skiftet her om eftermiddagen." (Mortensen 2020)*

At 04.00 in the morning several trucks are leaving the factory, and they will start to return around 10.00, if they do three trips, or around 12.00 if they do 2 trips. Around 15.00 several trucks return from the last of their trips and at 16.00 a new group of drivers meet at the factory to start their shift. A group of dispatchers at the Akafa factory plans the routs for the trucks and monitors the progress of the trips (Mortensen 2020)

The timing of the logistics operation means that the first trucks start to return from the northern part of Northern Jutland around the morning peak-hour around 7-8, where there is typically congestion at the Limfjord Tunnel. This sometimes causes delays but the impact on the production is not significant due to the safety stock. Typically, the factory has a safety stock of between 500.000 and 1.000.000 liters of milk waiting to be processed. Lack of milk because of traffic issues in the Limfjord Tunnel has therefore not been an issue as far as the respondent could remember. The only situation where the safety stock had been relatively low, maybe around 100.000 liters, had been in case of snow (Mortensen 2020)

Asked about whether the safety-stock could be reduced, and costs related to the safety stock reduced the respondent answered:

> *"Respondent: Well, there is no doubt… I think we would have the buffer anyway, because it also has to do with whether we have to do rearrangements regarding the production or if something else comes up. I think a relevant subject is that our drivers do not always arrive right on time. Often our drivers are stuck behind each other because they have become delayed. We have 10-15 trucks driving at the same time and of course they cannot all be here and unload at 16.00, because we only have 3 loading stations." (Mortensen, 2020)*

> *"Respondent: Altså der er ingen tvivl om… ej jeg tænker vi alligevel ville have den buffer, fordi det er også noget med hvis vi skal lave nogle omlægninger i produktionsøjemedet eller hvis der kommer et eller andet. Der hvor jeg tror at der vil være noget, det er at vores chaufførerikke lige rammer altid lige rammer klokkeslættet. Det er tit vores chaufførerenten holder oven i hinanden fordi de er blevet forsinkede. For vi har 10-15 biler der kører, og de kan selvfølgelig ikke alle sammen komme og læsse af kl. 4, for vi har kun 3 læssestationer." (Mortensen 2020)*

This leads to a focus on the costs that emerges in the logistics operations by Arla and how the events in the Limfjord Tunnel influences this. However, before we turn to this, we will stay a bit with the production cost, because the interviews revealed that the milk was actually not the critical part of the safety stock, the critical issue was packaging, and in relation to packaging events on the highways in Denmark had a significant impact. When asked about impacts of accidents the respondent replied:

> *"Respondent: … What we experience, and this is more when driving through Jutland. It is all of our packaging - we use a lot of tin cans and they take up equal amounts of space whether empty or full, so they take up huge amounts of space. With the cans we administer the stock very tightly, so sometimes it happens that we have a production stop because of lack of cans. This is due to*

the storage area being too small for storing cans for several days of productions. So when we agree on delivery at 14.00, then they shouldn't really arrive at 16.00 because then we might have run out of cans.

Interviewer: Well okay, so they are driving from south?

Respondent: They come from the south, yes, and it is typically if the traffic stops either by Aarhus, around Randers, or up here before Svenstrup. Then it happens." (Mortensen, 2020)

"Respondent: ... Det vi oplever, det er nok mere ned igennem Jylland. Det er jo alle vores emballager, vi bruger masser af blikdåser, og de fylder jo lige meget om der er fyldt noget i dem eller ej, så de fylder meget. Og med dem kører vi meget snært på lageret, så det hænder, at vi holder stille fordi vi mangler dåser, fordi vi ikke har plads til at have flere dages lager. Så det er faktisk sådan, at når vi aftaler kl. 14, så skal de helst ikke komme kl 16, for så kan det godt være at vi er løbet tør.

Interviewer: Nå okay, så det kommer nedefra (syd).

Respondent: Det kommer nedefra ja, og det er så typisk hvis det klokker både i Aarhus og omkring Randers og heroppe af og indtil Svendstrup. Så i forhold til det hænder (Mortensen 2020)

The respondent did an overall estimate of the cost of one hour of down-time due to delayed tin-can packaging, which arrives from either Odense or France, and thus in both cases travels up along the high-way in eastern Jutland. In total, depending on the product, the cost consisting of wage-cost to approximately 10 idle workers and the cost on one hour of lost production was between 50.000 to 100.000 per hour depending on the type of product being produced the given day. It should be noted that as the factory runs 24 hours a day 7 days of week, it is not possible to catch-up on delays in production. Asked about the frequency the respondent said that so far in 2020 (interview was conducted in August), the factory had been idle for more than one hour on three occasions due to delayed packaging. One of these occasions lasted approximately three hours. One of the mitigation processes used was sometimes to advance planned cleaning-stops in the production in case of lack of packaging if this was possible (Mortensen 2020).

The factory also received other materials for example cardboard and other ingredients, but for these the safety stock was higher, quote:

"Respondent: … it is cardboard and ingredients for other things, but we have a bigger stock of those things so it is not as often that we are hit by that. You can also say; I would really rather not have to, well had we been on the other side of the fjord, then it had really been problematic as we need everything more or less 'just in time'. We couldn't have done that, or we would definitely have had to build a lot of warehousing facilities." (Mortensen, 2020)

"Respondent: … der er jo pap og ingredienser til andre ting, men der har vi lidt større lager, så der er vi ikke så tit ramt af det. Men man kan sige, jeg vil virkelig nødigt have - altså havde vi

lagt på den anden side af fjorden, så havde det virkelige været problematisk, fordi vi har alt just in time mere eller mindre. Det havde vi ikke kunnet, eller også havde vi i hvert fald bygget lager en masse." (Mortensen 2020)

In the above we see two types of costs associated to the risk-management, one is the cost of maintaining the safety stock for the production and the other is the cost when the safety stock is depleted, in the case of Arla exemplified by the production stopes related to delays in tin-cans.

Let us not turn to the costs that emerges in Arlas logistics operations following delays. Here the main issue is that if one driver is delayed, then he may not reach one of the three delivery-stations in the factory on time, according to the plan, or be late for the milk collection, which may cause issues for the farmer in case the tanks at the farm is full, meaning that it is not possible to start milking the next round of cows according to plan.

As the following quote shows delays in delivery of milk to the factory has no impact on the production cycle due to the safety stock as discussed above, but on the driver side, the consequence is waiting time and thus wasted salary. What we see here is a cost for the driver, which is not only the extra time he or she spends on the road waiting in queue, it is an extra time he or she spends at the factory and possibly also an extra time the next driver of the truck waits. This is worth noting, the cost is larger than the direct cost of waiting on the road in a queue.

"Interviewer: If you take a day where a car is blocking the tunnel - can you try to explain what happens? Is it the driver who handles it, or does the message go to you or what?

Respondent: The driver calls us if he can see that it is going to take some time. Then he calls the guard on duty - if you can say so - and tells that he is in the tunnel and he tells how long time he thinks he will be there. Typically, they make a deal by saying 'okay take another 15 minutes' or 'we see how pressed some of the other drivers are'. They track where the trucks are and can see the status is. So they decide, they might reroute some trucks or put another one on the road. So is they tell the driver to call again in 15 minutes - they have people on duty 24/7 on the station - so they receive calls all the time. It is on a daily bases that things are changed, where they change the routs, or tell someone 'then you have to drive to that other guy instead'. We also have trucks parked in some places where they can unload if one driver for example have picked up something at a farmers' place. Then we have some trucks to the west, so that if they aren't.

Interviewer: Ok, as a temporary transport?

Respondent: So that we can have a temporary storage, which they can transport later on by attaching the trailer. Then they can unload and maybe drive to get another loading.

…so there are a few at work all the time everyday keeping track on where the drivers are placed, who has a broken truck, who is stuck in queue, or if there are snow on the roads. But there is no doubt that the largest pressure is in the afternoon and in the morning. At those times they are almost out of the tube [Limfjord Tunnel] - literally." (Mortensen, 2020)

"Interviewer: Hvis man tager sådan en dag, hvor der holder en bil på tværs i tunnellen - kan du prøve at forklare hvad der sker? Er det chaufføren der håndterer det, eller går beskeden til jer eller hvordan?

Respondent: Han ringer så ind, hvis han kan se, at det her kommer til at tage noget tid. Så ringer han ind til vagthavende - hvis man kan sige det sådan - og siger at nu holder han i tunellen og umiddelbart tror han det kommer til at tage så og så lang tid. Og så typisk laver de så en aftale om at sige okay, tag lige et kvarter mere eller hvor pressede er vi på andre. De følger jo med i hvor bilerne er og så kan de gode se hvilke af bilerne, der er hvor. Så kan de se om det giver mening, at de skal have omdirigeret nogle biler, eller sat en ny i gang. Men hvis det er sådan at de siger 'ring lige igen om et kvarter' - de har også vagt 24/7 inde på stationen - så de sidder også og modtager opkald hele tiden. Det er dagligt, der bliver lavet noget om, hvor vi så rykker rundt op ruter eller siger 'nå men så kører du over til ham i stedet for'. Vi har også biler til at stå nogle steder, hvor de så kan køre ud og læsse af f.eks. hvis han har været ude og hente ved en eller anden (land)mand. Så har du nogen biler ovre vestpå, så hvis ikke de er så store.

Interviewer: Nå som sådan en midlertidig transport

Respondent: Så kan vi lave sådan en midlertidig opbevaring, som kan de selv køre over og så tage hængeren med. Så kan de læsse af og så kan de måske godt køre over og tage en mere...

... Så der sidder egentligt et par stykker hver dag hele tiden og holder styr på hvem befinder sig hvor, og hvor hvem er kørt i stykker, og hvem holder stille, eller er der sne på vejen. Men der er ingen tvivl om, at det største tryk, det er her om eftermiddagen og om morgenen, der er de næsten ude af røret - bogstavelig talt". (Mortensen 2020)

Even though the trucks are monitored, and plans adapted continuously, one issues stands out as the main obstacle for efficient planning and this is the Limfjord Tunnel. The factory has three unloading bays where the milk trucks can unload, and it takes approximately 30 minutes to unload. Therefore, the day is planned in slots so that the trucks return to the unloading bays every 30 minutes.

"Respondent: … So it is all timed so that 'this guy' shall arriv at 8.00 and 'that guy' shall be here at 8.30am and so on. There are a lot of things which have to fall into place regarding the planning… and of course it never fits. The delays are often caused because of the bridge and the tunnel. So it can be difficult - it is costly but I would say the actual production is not influence by it. But our drivers and the trucks are influenced by it of course, because 'Hans' is not always here when 'Kurt' is ready to get onto the next truck" (Mortensen, 2020)

"Respondent: ....Så det hele er timet efter at 'ham der' skal gerne komme kl. 8 og 'ham der' skal gerne komme kl. 8.30 og så videre. Der er mange ting, der skal falde i hak med planlægningen… ... Og det passer selvfølgelig aldrig. Det går ofte galt netop på grund af broen og tunnellen. Så det kan være svært - så det koster noget, men selve produktionen her, der vil jeg sige, at vi ikke

mærker noget til det. Men vores lastbilchaufførerog bilerne de mærker selvfølgelig noget til det, fordi det ikke er altid, at Hans er kommer hjem, når Kurt står og er klar til at hoppe på den næste bil. " (Mortensen 2020)

Describing the situation around unloading in more details the respondent elaborates:

"Interviewer: How big loading-slots do you operate with?

Respondent: There is a demand for how fast we shall unload a tuck, but that is of course because the timing has to be as tight as possible. So, we can have 2 hours where no trucks are scheduled to arrive because that is how the time plan could work out that day. But usually, it is approximately 30 minutes per truck. Or that is the demand per truck and if we take a little longer time then it is okay, because then we can count in delays. But sometimes when they arrive from their last run, we can have trouble making it…

Interviewer: So, they are here around 16.00?

Respondent: Yes, then we are extremely busy. There are many trucks unloading, loading and the staff is changing. But there is no doubt that there will be a postponement every day; a driver cannot shift at 16.00 if he is stuck in the tunnel, because well, then he is in the tunnel. And the same is applicable for the guy who just clocked in - he does not wait with clocking in until the truck arrives. So, it is a cost to us - no doubt about that." (Mortensen, 2020)

"Interviewer: Hvor store tanke-slots arbejder I med der?

Respondent: Der er krav til hvor hurtigt vi kan læsse en bil af, men det er selvfølgelig også fordi den timing skal være så snæver som muligt. Så vi kan også godt have 2 timer, hvor der ikke er planlagt, at der kommer nogen biler fordi det er sådan det lige passer den dag. Men som regel, så er det cirka 30 min per bil. Eller det skal der være per bil og kan der blive lidt mere så gør det ikke noget, for så kan vi tage lidt højde for forsinkelser. Men det er af og til sådan, når de kommer hjem fra sidste tur, så har vi svært ved at få det til at…

Interviewer: Altså her omkring kl. 16.00?

Respondent: Ja, så er der dælme tryk på herude. Der er mange biler der læsser af, læsser på og skifter mandskab. Men der er ingen tvivl om, hver dag vil der være noget forskydning; en chauffør kan jo ikke påregne, at han skifter kl. 4, for hvis han holder ude i tunnellen, ja så holder han jo altså ude i tunnellen. Og det samme med han som er mødt ind, så er han jo stemplet ind, det er jo ikke sådan at han venter til bilen er kommet hjem. Så det koster nogen penge - det er der ingen tvivl om." (Mortensen 2020)

In case of significant delays extra trucks are deployed to solve the problems:

"Respondent: …and should it end in disaster (with delays) then they always have an extra truck which they can put on the roads. It can of cause also be because of a truck breaking down, then

there have to be a couple of spare trucks which can be used, if it goes wrong. The same applies if they are very delayed in the motorway and everything is shut off. So if everything is sliding, then they are putting another truck on the road to get the milk. There is a certain dependability at the farmer if it is close to milking. If he has no space left in his tanks, then he cannot commence milking." (Mortensen, 2020)

"Respondent: ... og går det helt galt (med forsinkelse) så har de altid en ekstra bil, som de kan sætte ind. Det kan selvfølgelig også være en bil som går i stykker, så skal der jo være et par reservebiler, som kan skydes afsted, hvis det er, at det går galt. Det samme gælder hvis de virkelig bliver forsinkede på motorvejen, og det hele er lukket til. Så har vi jo også hvis det hele begynder at skride, så sætter de en ekstra bil ind og kører ud og henter det mælk. Der er jo også en vis afhængighed hos landmanden, hvis det er tæt på malkning. Så hvis ikke han har plads i tanken, så kan han jo ikke komme i gang med at malke. " (Mortensen 2020)

Just as there is safety stock in relation to the production line, we see here that there are safety stock in relation to the logistics operation in the form of extra trucks and strategically located milt-tank trailers in the more remote sites of Northern Jutland. This is another issue we shall return to later, the safety stock needed in the form of extra vehicle capacity to accommodate delays. Let us now turn to the other 1PL case.

4.2 Lantmännen Schulstad A/S's delivery of bread

Schulstad delivers fresh bread to shops across all of Denmark seven days a week, and in doing so Schulstad delivers to almost all grocery chains across Denmark. To do this the company owns and operates 70 trucks. During the latest 8 years Schulstad has made agreements with other competitors to optimize its logistics operations. Therefore, as an example, when Schulstads trucks deliver to Rema 1000 in Aalborg Øst, then they bring Schulstad bread and also products from the two competitors Kohberg and Pågen. This setup has been made to minimize both cost and environmental emissions (Holm 2020).

The logistic operation is centered around the basis goal that the fresh bread shall be available in the shops from the morning i.e. when then shops open at 8.00. The daily rhythm starts in the afternoon where the shops deliver their orders for bread the following day to Schulstad. The deadline for orders is at 17.00. Bread ordered before 17.00 has to be delivered to the shops the next day before 08.00 in the morning. This means that where it is possible given noise and nighttime delivery regulations the bread is delivered during the night, but in a lot of locations delivery is only possible after 7.00, when "normal delivery" is possible, and before 8.00 when the shops open.

The nighttime delivery is the result of a close collaboration with the Ministry of Environment and Food and the consultant company Rambøll, quote:

> *"Respondent: We have teamed up with Rambøll and The Ministery of the Environment and have worked on a case the last 6-7 years. We have worked on how to avoid congestion from 6.00 to 9.00, where we experience the most traffic on the roads?. How can we with our trucks reduce noise, so that we can drive noiseless at night. Therefore, we have actually invested in hybridcars. We have invested in Piek-certified equipment, which is the Netherlandish quality norm for noise and all of our cars today are Piek-certified. That is not completely true, we have 5 left which is not certifies yet. But 65 out of 70 cars are Piek-certified, meaning that the undercarriage has been changed to reduced noise. The sides of the car are noise reducing. The lift is special so that it is not noisy. The reverse alarm on the truck is removed and we have replaced it with a camera instead. The driver is instructed not to talk on the phone and so on. A whole range of efforts are what has reduced noise." (Holm 2020)*

> *"Respondent: Vi har gået sammen med Rambøll og Miljøministeriet, har vi faktisk haft en case de sidste 6-7 år. Hvor vi har arbejdet på, hvordan kan vi undgå trængsel fra 6 til 9, hvor der er mest trængsel på vejene? Hvordan kan vi med vores biler reducere støjen, så vi kan køre støjfrit om natten. Derfor har vi faktisk investeret i hybridbiler. vi har investeret i Piek-certificeret udstyr, som den hollandske kvalitets norm omkring støj, og har alle vores biler i dag Piek-certificeret. Det passer ikke helt, vi har fem tilbage, der ikke er det. Men 65 ud af de 70 er Piek-certificeret, dvs. at vognbunden er ændret så det reducerer støj. Siderne på bilen er støj reduceret. Liften har en special lift, som ikke støjer. Bakalarmen på lastbilen er fjernet og så har vi sat bakkamera på i stedet for. Chaufføren er instrueret, at man taler ikke i mobiltelefon osv. osv osv. en hel pallette af ting som har reduceret støjen." (Holm 220)*

The reason why this quote is important is that these investments described in relation to make nighttime delivery possible has been done by Schulstad to avoid driving in the peak-hour congested traffic. In other words, these costs are not costs inflected on Schulstad directly as a consequence of delays, it is cost spent up-front by Schulstad to avoid costs associated with traffic congestion and peak-hour traffic. In other words, as I shall return to later, this is costs that occurs "before the road".

Returning to the logistic operation, after the orders for the following day has been placed at 17.00, the next step is that Schulstad starts to consolidate the goods. Between 17.00 and 20.00 Schulstad receive goods from Kohberg and Pågen. At 20.00 Schulstad start picking orders for the individual shops and thus routes, and by 22.00 the trucks start leaving the factories/centrals for the delivery trips. For this purpose the routs are planned using route optimization tools to keep the driven distance to a minimum, and many trucks does two trips, one night-time delivery and one morning delivery. Although a system is used to suggest the overall routes, the local knowledge of the driver is also included in the planning.

The trips start at one of the three factories/terminals Schulstad operates, one is located in Avedøre holme, one is located in Vejle and one is located in Pandrup. The factory/terminal in Pandrup supplies the routes covering the northern part of Jutland north of Randers. The trucks that have to reach delivery points south of the Limfjord, for example in Hobro and cities in that part of Jutland, normally crosses the Limfjord Tunnel before peak-hour either to do nighttime delivery or to be in position at 7.00 for the morning delivery.

During the day there is also transport through the Limfjord Tunnel. The factory in Pandrup produces organic products for all of Denmark, and therefore there is a transport of inputs for the production to the factory during the day, as well as transport of final organic products from the factory to the other two terminals. For the linehaul between the terminals the transport company Ole Larsen is used, and during the day Ole Larsen transports products from Pandrup to Vejle and vice versa, so that the trucks are not running empty.

The following is an example of the consequences of an event in the peak-hour morning traffic in the tunnel:

> *"Respondent: Well, if it is closed in the morning. We have a truck coming in from Pandrup at 7.00 and that is in the tunnel at 8.00 and he has to get to Vejle, and thereafter on to Avedøre and then back to Pandrup. And if we have a stop in the Limfjord tunnel then he cannot respect his hours of driving time and rest, and then we need another driver on the truck. Or else he will be late with the goods and return here late afterwards. And that creates delays and extra costs. Is it really difficult to put numbers on, but it does lead to costs. We have sorting activity in Pandrup and 12 men sorting. If they have to wait for the freight for 1 hour then it will be 12 hours of non-productive time." (Holm 2020)*

> *"Respondent: Jamen, hvis den er spærret om morgenen. Vi har en bil der kommer fra Pandrup kl 7 om morgen, og den landet i tunnellen omkring kl. 8, og han skal så til Vejle og så videre til Avedøre og tilbage til Pandrup. Og hvis vi har et stop i Limfjordstunnellen, så kan han jo ikke*

overholde sine køre/hviletider, så skal vi have en ekstra chaufføer på. Eller også så skal, så kommer han for sent med varer og kommer for sent retur. Og det skaber så forsinkelser og ekstra omkostninger. Det er rigtig svært og sætte kr. og øre på det, men det koster jo penge. Når har sådan plukke aktivitet i Pandrup, der har vi 12 mænd der går og plukker. Hvis de nu skal vente en time på varerne. Det er 12 timers spildtid." (Holm 2020)

Another issue is if the driver runs out of driving time on route:

"Respondent: The driver he risks suddenly being parked somewhere. He is allowed to drive for a certain number of hours due to driving and resting time regulations and if he is standing still for too long, then he risks not making it to the destination. Then we need another driver to drive and replace him." (Holm 2020)

"Respondent: Chaufføren han kan risikere at han pludselig holder et eller andet sted. At han ikke må køre videre pga. køre/hviletid, han må køre et vis antal timer og hvis han holder for stille for længe, så kan han risikere han ikke kan komme frem, og så skal vi jo have en anden chaufføer ud og afløse ham." (Holm 2020)

This is an issue we shall see also in the analysis of Vendelbo Spedition, where it sometime happens that drivers run out of driving time around the Limfjord Tunnel, leading to either 1 or 2 drivers having to come and pick him up. Regarding the planning the obvious question is the amount of slack build into the plans during the day:

"Interviewer: Regarding the planning of the routes, do you operate with some kind of slack to accommodate such events?

Respondent: No!

Interviewer: [Laughing] Okay, that was pretty direct!

Respondent: [Laughing] Well, well you know what, we are so reliable regarding being on time, that I actually went to Pandrup yesterday and talked with the people. We talked about when the truck leaves Vejle, it is evening, and therefore usually not a problem, only if it is really bad. The driver leaves Vejle at 17.00 and has to be in Pandrup at 20.00, it is actually 19.00, for that in particular that drives at this time. [Interviewer: Yes]. But if he is 15 minutes late, then all the trucks leaving will be delayed, and that in the end constitutes a cost to us. So, we are often down to 10 minutes, we are seeking 10 minutes, because the time deadline is so tight, so it is the small decimals we are seeking." (Holm 2020)

"Interviewer: Er der sådan en, hvad kan man sige, jeres planlægning af turen, er der noget slack ift. sådan nogle hændelser her?

Respondent: Nej!

Interviewer: [Griner] okay, den var meget kontant.

Respondent: [Griner] jamen det, jamen ved du hvad, vi er så tidsstabille, så at jeg faktisk har været i Pandrup i går og tale med folkene.Vi talte om, når bilen kører fra Vejle, det er aften, så det er ikke så normalt et problem, det kun der hvor det er rigtig slemt. Han kører fra Vejle kl. 17 og skal være i Pandrup kl. 20, det er så kl. 19, for det specielt der løber på det tidspunkt [Interviewer: ja]. Men hvis han kommer et kvarter for sent, så får vi alle biler forsinket afsted, og det koster altså i sidste ende. Altså vi er ofte mere ned på 10 minutters, vi går efter 10 minutters, fordi det er, tidsterminen er så stram, så det er helt de små decimaler vi går efter." (Holm 2020)

The timing is important for the operation as several trucks does two trips during the night, one with nighttime delivery and one around 7 when the shops open and the staff can receive goods. Therefore, if the trucks delivering the goods to the terminal arrives say 15 minutes late in the evening, then the picking for the trucks is 15 min delayed, and then the first trucks leave 15 minutes late for their first trip and are thus also 15 min delayed for the next trip. This in turn means that the delay does not need to be long before it becomes necessary to bring in extra trucks for the deliveries to keep them on time in the morning before opening hour. We shall also see in the Danske Fragtmænd case later how delays can live for a long time in the terminal operations due to this dynamics.

This delay in interesting because here we see an issue which we shall return to later – small delays do not have any significant consequence whereas longer delays do have a significant consequence. In other words, the costs of delays are not linear in rising, they are low in the beginning and then above a certain threshold rises sharply.

"Respondent: … I will say, we have some drivers whom are pretty flexible and agrees to take an a little extra time at work. If it concerns 15 minutes, we do not take any action, but if it is 30 minutes or more, then we have to spilt the order.

Interviewer: Okay, how many trucks do you typically call in you are one hour behind?"

Respondent: Well, then it is that we have to get an extra truck in. Usually it does not affect all routes at the same time, but 2 to 3 trucks can easily be needed." (Holm 2020)

"Respondent: ... Jeg vil sige at vore chauffører, som er ret fleksible, og er okay med at skulle møde lidt ekstra. Så et kvarter gør vi ikke noget, men en halv time eller mere gør, at vi eri nødt til og dele, dele ordren.

Interviewer: Okay, hvor mange biler tager I så typisk ind, hvis det hele hænger en time sådan?

Respondent: Jamen altså, så er det jo at vi skal have en bil ekstra, det er jo sjældent alle ruter, men 1 til 3e biler, kan vi hurtig komme til at tage ind." (Holm 2020)

Small delays are managed by the drivers, larger delays mean that it is necessary to bring in extra trucks and drivers. Typically, queues are reported among the drivers and evasive action taken. This could be to use the Limfjord Bridge in case the Limfjord Tunnel is blocked, or even to go east and

pas the fjord at the Aggersund Bridge instead. In the factories/termianls the plans are constantly monitored, and when news about a delay reaches the terminal planning starts to mitigate delays. This typically involves calling customers to inform them about delays.

> *"Interviewer: What about when you hear about it, what usually happens then?*
>
> *Respondent: Then vi bring in an extra truck or how many is necessary. It is very different how many trucks that are needed. And then we might also call the stores, to tell 'you know what, somethings has come up so we will have a delay of 30 minutes'. [Interviewer: Okay]. I know that then the stores won't have the bread ready for their opening, but then the consumers must take the bread which is already on the shelves. [Interviewer: Yes]. That is how it turns out sometimes.*
>
> *Interviewer: Who does what in this scenario? Is it the terminal which controls everything or is it mediated through you when there is contact to the customers?*
>
> *Respondent: No, the termina in Pandrupl is control of it all and they contact our customer service. We have a department for customer service in Vejle, which manages the whole country. They take action by either writing or calling the customer, depending on the agreement." (Holm 2020)*
>
> *"Interviwer: ... Hvad så når I hører det, hvad sker så typisk?*
>
> *Respondent: Vi, så tager vi en ekstra bil ind eller hvor meget der nu skal til. Det er jo så forskelligt, hvor meget der er. Og så kan også godt finde på, så ringer vi til butikkerne og siger, ved I hvad, der er altså sket det er, så vi kommer, vi kommer en halv time for sent. [Interviwer: Okay] Så ved jeg godt, så har butikkerne ikke brødet til åbningstid, men så må forbrugeren tage det brød de har [Interviwer: ja]. Det jo sådan det gange sker.*
>
> *Interviwers: Hvem gør hvad i den henseende, er det terminalen, der styrer det hele heroppe eller kører det over dig, som man sender det ud fra virksomheden-?*
>
> *Respondent: Nej terminalen i Pandrup styrer det selv, og så kontakter de vores kundeservice. Vi har sådan en kundeservice siddende i Vejle for central for hele landet. Og de tager aktion på enten og skrive ud til kunden eller ringe ud til kunden, alt efter hvad aftalen er." (Holm 2020)*

Worth noting is also that the drivers are closely involved in the planning to utilize their local knowledge:

> *"Respondent: We have a central function which is placed in my department here and they make drafts for routes. Then we send the drafts to the given terminal and say: here is a draft fro a route. That suggestion is then discussed with the leaders and the drivers so that all have a chance of actively optimizing. And the drivers has to approve the route under the certain conditions, because the drivers always knows the small shortcuts or alternative possibilities. And we have a lot of great drivers who come with suggestions: 'I have driven in this area before, I drive, for example, in Aalborg Øst, if you take that, so if I take that shop before this one, then I avoid some*

congestion because then I won't be stuck in that intersections where there is also issues." (Holm 2020)

"Respondent: Vi har en centralfunktion, som sidder i min afdeling her, som laver udkast til ruter. Og så gør vi det, at vi sender det ud til den enkelte terminal og siger: Her har vi et forslag til rute. Det vender vi så med lederne og chaufførerne så alle har mulighed for aktivt at optimere, Og chaufføren skal ligesom sige god for at det kan køres, for under de konditioner, fordi er altid chaufføren, der kender alle de små fine genveje og muligheder for, hvad kan vi gøre her osv. Og vi har mange gode chauffører, som kommer ind og siger: ved I hvad jeg kørt i det område, jeg kører fx i Aalborg Øst, hvis du nu tager, hvis jeg nu tager den butik før jeg tager den butik, så sparer jeg faktisk noget trængsel, for så holder jeg ikke og venter i det kryds, hvor der altid er bøvl." (Holm 2020)

As the delivery to many shops occurs between 7.00 and 8.00 in the morning, congestion in the Limfjord Tunnel in traffic entering from the north in the morning is a problem for Schulstad also, as this is where a large part of their trucks drives through the tunnel.

Making the situation in the Limfjord Tunnel in the morning even more an issue for Schulstad is the rules regarding nighttime delivery in Aalborg, as the following quote shows:

"Respondent: …And in Aalborg, for example, we, there are many limiting restrictions, because Aalborg has not been a very open municipality when it comes to the debate concerning noise reduced delivery. They are more focused on their inhabitants being able to sleep at night. I understand that. But I also think that when a firm wants to invest in equipment that can reduce the noise so that it actually becomes noiseless. It would help a lot of stores to get delivery without noise. And the congestion we have in the Limfjord Tunnel - if we drive at night, then there is no congestion - and by driving at that time we won't block the tunnel. But if we have to deliver in Aalborg between 7.00 and 8.00, then we will be in the traffic alongside all the other vehicles." (Holm 2020)

"Respondent: … Og i Aalborg fx er vi er der mange leveringsrestriktioner, fordi Aalborg har ikke været den kommune, som har været så åben for debatten om støjsvag levering, men går mere efter at borgerne, de skal kunne sove om natten. Det kan jeg også godt forstå. Men jeg synes jo, når en virksomhed vil gå ud og investerer i udstyr der kan, kan reducere støjen, at det faktisk blive mere støjfrit. Det vil hjælpe rigtig mange butikker til levering uden støj. Og dvs. fx den trængsel vi har i Limfjordstunnellen, hvis vi nu kører om natten, der er jo ingen trængsel... ... Og i og med vi gør det, så propper vi ikke Limfjordstunnellen til. Men hvis vi skal levere Aalborg kl mellem 7 og 8, så kommer vi samtidig med alle de andre biler." (Holm 2020)

Later the respondent elaborated on the consequences of the regulation in Aalborg:

"Respondent: Well, as I told you, we deliver bread to all clients, to Rema 1000, Spar, Meny, Coop stores and so on. And when I drive through Aalborg then my route is star-shaped because we can reach some store early and other late. This leads to us circling around far too much – zigzagging through the city - and it is not only us. It is also applicable for Arla, because they have their own

trucks as well and so on. We are many cars, trucks and if it was made optimal you would get a completely different flow in the city center." (Holm 2020)

"Respondent: Jamen nu kan jeg, som jeg sagde til dig, så kører vi jo brød til alle kunder, til Rema 1000, til Spar, til Meny, til Coop butikker osv. Og når jeg kører ind igennem Aalborg, så kører vog jo i stjernekørsel fordi nogle butikker kan vi komme til tidligt og andre sent. Og dvs. at vi lægger og cirkler rundt alt for meget zik zak inde i byen, og det jo ikke kun os. Det er jo også Arla, det jo også deres egne biler osv osv. Vi er jo rigtig mange biler, lastbiler, som hvis man gjorde det optimalt, så ville du få et helt andet flow i byen. " (Holm 2020)

Here we see the relationship between the critical infrastructure in this case the Limfjord Tunnel and the adjacent road-network, i.e. the network in Aalborg city and the rules etc. applying to this network. As I shall return to later, this may be understood as costs "around the road". If the rules regarding this network was changed Schulstad could drive the majority of their transports by nigh where almost no significant delays occur, instead of in the peak hour traffic in the morning in both the tunnel and the city. We shall return to this issue in the case of Jørn Kannik A/S, where we shall see how the rules for delivery in pedestrian areas in Aalborg also increased the number of trucks operating in the network. It is important to note that this is not a report on challenges of logistics in urban ares. However, it is worth underscoring that the interviews shows that the issues the companies face in the form of congestion and delays on the key infrastructure, in the Limfjord Tunnel, is intensified by the planning in the adjacent road network, which in some cases forces the companies onto the roads in peak-hours or increases the number of trips needed to deliver the freight.

4.3 AVAS A/S

AVAS A/S is a transport company located at Kystvejen in Nørresundby, just north of the Limfjord Tunnel. The company owns 85 trucks and leases extra trucks according to the demand. On average the company operates around 100 trucks and in the busiest times of the year it operates around 110 trucks. AVAS has four business areas: The first is crane, lifts and special transports, i.e. large transports. The second is transport of concrete cargo. The third is transport of asphalt, AVAS is driving asphalt for the company Colas, and Colas' asphalt factory in Northern Jutland is also located in Nørresundby at Sundsholmen just north of the Limfjord Tunnel. The fourth is normal transport customers including transport of waste-containers for construction companies and private consumers (Kjelgaard 2020).

The operation is organized so that the trucks in concrete element busines segment starts their trips Sunday evening and then the drivers sleep in the truck and does not return to the headquarter before Friday evening. A number of the drivers in the crane and special transport business area does the same and sleeps in truck during the week. The rest of the trucks in the crane and special transport business area starts every day at the headquarter and these mainly operates in Northern Jutland. These trucks typically start the day so that they are in position at the first customer around 6 in the morning, which means that they typically drive through the Limfjord Tunnel in the south direction between 4 and 5 in the morning well before peak-hour traffic. The trucks in the asphalt business area are the ones hardest hit by congestion in the tunnel as they have to constantly return to the Colas' concrete factory at Sundsholmen in Nørresundby just north of the Limfjord Tunnel. They both bring raw material for the production and asphalt from the factory to the roadworks where it is needed. In the normal transport business area, the dispatchers seek to plan around the peak-hour traffic.

The daily operation is planned by the dispatchers in AVAS so that the drivers, as far as possible, avoids crossing the Limfjord Tunnel in peak-hours:

> *"Respondent: We plan, if possible, so that we to cross it [Limfjord Tunnel] as little as possible. If we are on the one side, we have to be active there and if we are on the other side, then we carry out activities there. So we cross when the traffic is low. That is the strength of the dispatchers. It is to solve this." (Kjelgaard 2020)*

> *"Respondent: Vi planlægger for så vidt muligt, at vi ikke skal krydse den [Limfjordstunnelen] så tit. Hvis vi er på den ene side, så skal vi gerne beskæftige os på den side, og hvis vi er på den anden side, så beskæftiger vi os der. Så vi krydser, der hvor der er mindst trafik. Det er sådan set det, der er disponenternes styrke. Det er at få det til at gå op." (Kjelgaard 2020)*

To avoid the tunnel work is also planned so that the trucks make the least possible number of returns to the headquarter of AVAS:

> *"Respondent: Yes, they should preferably be that [on constant trips between clients] but of cause some are here to load sand and some are here to unload sand. There are also some here to get tools which are needed for their tasks. So we do cross the fjord and we do it many times, but we*

try to limit it and to make sure they have everything needed when they leave in the morning. If we can clock in earlier on construction sites or on tasks, then we prefer to do so because then we are up and running." (Kjelgaard 2020)

"Respondent: Ja, det skulle de gerne være [på konstante ture mellem kunder], men der er selvfølgelig nogle hjemme og hente sand, og der er også nogen, der er hjemme og tippe sand af. Der er også nogle hjemme og hente noget andet værktøj, de skal bruge til deres opgaver, så vi krydser fjorden og vi gør det også mange gange, men vi prøver at begrænse det og sørge for at de har det med ud om morgenen, når de kører ud. Hvis vi kan møde tidligere på byggepladser eller ved opgaver, så vil vi gerne det, for så er vi i gang." (Kjelgaard 2020)

When the traffic in the tunnel breaks down due to for example accidents the dispatchers try to either plan alternative routes, for example through the city center across the Limfjord Bridge, or they try to move pickups and delivery times forward to accommodate the delay.

"Respondent: … then we typically call the customer and say 'they are stuck in traffic down there, can we deliver sand instead?' if they had ordered gravel. So we change the task, so we keep being productive. Off course we can get caught in it, but then they take a cup of coffee and wait for the road to be cleared again." (Kjelgaard 2020)

"Respondent:... så ringer vi typisk til kunden og siger "nu holder de i kø dernede, kan vi komme med noget sand i stedet for", hvis de skulle have grus. Altså ændre opgaven, sådan at vi bliver ved med at være produktive. Vi kan selvfølgelig blive fanget i det, men så må vi give os til at drikke kaffe og så vente på at der bliver ryddet op. " (Kjelgaard 2020)

There were two kinds of delays according to the respondent, the normal daily congestion delay in peak-hours and the unforeseeable events.

"Respondent: Well, the normal (delay as following the daily congestion) we take that into consideration. It is so deeply rooted in the way they plan the trips that they keep out, I won't say it isn't a problem for us because surely we are influenced by it, but we are actually relatively good at staying out of the rush hours. But when the sudden [events] appear, then it is just a hassle." (Kjelgaard 2020)

"Respondent: Altså den normale (forsinkelse som følge af trængsel), den tager vi hensyn til. Det er simpelthen så indgroet i den måde de planlægger kørslen på at de holder sig af - jeg vil ikke sige, at det ikke er et problem for os, for vi bliver selvfølgelig ramt af det, men vi er faktisk rimelig gode til at holde os af myldretiden. Men når der kommer nogle pludselige [hændelser], så er det bare noget bøvl." (Kjelgaard 2020)

The planning is tight in AVAS and therefore unforeseeable delays do not need to be long to cause problems:

"Interviewer: Is there something timewise influencing this? If you are stuck in one of the unforeseeable delays how long time can then pass before it starts to become a problem to you? I'm thinking if it is critical after 30 minutes or if 1,5 hours has to pass before it is critical.

Respondent: No no, just 5 minutes after, then it is a problem.

Interviewer: Why?

Respondent: Because our time schedule is so tightly planned. 80% of all of our jobs are 'just in time', where we might need to be at a lift task at 10.00. And a container truck has to deliver at 10 to 15 places a day and most of these tasks are on exact time. So there are no extra time scheduled for all these tasks." (Kjelgaard 2020)

"Interviewer: Er der noget tidsmæssigt i det? Hvis du holder stille ved en af de her uforudsete forsinkelser, hvor lang forsinkelse kan der være før at det begynder at blive et problem for jer? Jeg tænker sådan om det er efter 30 minutter at planerne begynder at ramle eller skal der gå 1,5 time.

Respondent: Nej nej, det er jo ikke andet end 5 minutter efter, så er det et problem.

Interviewer: Hvorfor det?

Respondent: Det er fordi vores planlægning kører så stramt. Det er jo just in time med 80% af det vi laver, hvor vi eksempelvis skal være til stede til en hejseopgave kl. 10. Og en containerbil er typisk mellem 10 og 15 steder på en dag med en container og det meste af det er på klokkeslæt. Så der er ikke indlagt ekstra tid til alle opgaver." (Kjelgaard 2020)

As an example of how the planning is moved the respondent explained that the respondent typically monitors the trips carefully to make sure that the trucks are on the plans made and to see of the plans have to be adapted:

"Interviewer: The timeslots you work with, how tight are they when you are on a task?

Respondent: They fit. That's how tight they are.

Interviewer: Do this mean that you drive out so that you are there right on time when arriving?

Respondent: Yes, but we have to be there within a slot of 5-10 minutes.

Interviewer: Do your drivers or dispatchers schedule the routes?

Respondent: It is the dispatchers. That is what has built our business, to there exactly on time and that you can count on this.

Interviewer: But that must means that it is extra bad if you are delayed?

Respondent: It creates a lot of challenges and a lot of extra work. A typical day, looking at his task, he will drive to the assignment, and if it is planned to last 4 hours, then he will call back 2 hours into the task to verify that it fits with the time planned. Because, it is a huge challenge, if he is done 1 hour early, then we need to replan and move the next assignment forward, have another task put into the plan or swap plans. And if the driver is delayed, then we have to let the next customer know, so they can spend the time doing something else. Because the worst customer is the one standing and waiting. It happens, but it must not happen. It does not happen often.

Interviewer: What is the cost when it happens? Or who pays for it when it happens? Do you?

Respondent: The customer won't.

Interviewer: But what is the economy if there is an accident and you are 15 minutes late?

Respondent: Well, it is only 15 minutes then I might be able to speak my way out of it. But if it is a load of concrete elements for the Carlsberg Byen in Copenhagen and we have to be there at 9.00, at the construction site, there a mounting team and a big crane costs 12.500 kr per hour. Then you can do the math if they have to wait for 1 or 1,5 hours. I'm charged for all of those costs.

Interviewer: That means you get a supplementary bill?

Respondent: Yes.

Interviewer: How often does it happen that you get a supplementary bill?

Respondent: Probably 5 to 10 times a year. One of the things we have done the last 2-3 years is to establish sites in Aarhus, Vejle, Odense and Køge so we can have buffer warehouses." (Kjelgaard 2020)

"Interviewer: De timeslots I arbejder med, hvor stramme er de, når I er ude på opgaver?

Respondent: De passer. Så stramme er de.

Interviewer: Det vil sige I kører ud sådan at det lige præcis passer med tiden.

Respondent: Ja, men vi skal ramme indenfor 5-10 minutter.

Interviewer: Er det jeres chauffører, der lægger ruten eller er det jeres disponenter?

Respondent: Det er disponenterne. Det er det, der har bygget vores forretning, det er at komme til tiden og at man kan regne med det.

Interviewer: Men det betyder vel også, at det må brænde ekstra, hvis I ikke kommer til tiden?

Respondent: Det giver en masse udfordringer og en masse ekstra arbejde, for en typisk hverdag for en chaufføor - når vi snakker opgaven - så kører han derhen, så hvis opgaven er sat af til 4 timer, så når vi halvt ind i opgaven ved 2 timer, så skal han melde tilbage om det passer med tiden. For det er en stor udfordring, hvis han er færdig en time før, for så skal vi gerne have den næste opgave rykket frem eller have sat en anden ind og byttet rundt. Og bliver han forsinket så skal vi have givet besked, så den håndværker eller kunde kan give sig til noget andet, for den værste kunde, det er ham som står og venter og det må ikke ske. Det sker, men det må ikke ske. Det er heller ikke ret tit det sker.

Interviewer: Hvad koster det, når det sker? Eller hvem betaler når det sker? Det gør du?

Respondent: Kunden vil ikke.

Interviewer: Men altså hvad er økonomien, hvis der er et uheld og du kommer 15 minutter for sent?

Respondent: Jamen 15 minutter kan jeg måske tale mig ud af, men hvis det er et læs elementer vi skal aflevere i Carlsberg byen i København og vi skal være der kl. 09.00 - og der skal vi være på pladsen - ellers så koster et montagehold med stor kran 12.500 kr i timen. Så kan du selv regne det ud, hvis de skal vente 1-1,5 time. De omkostninger ryger direkte til mig.

Interviewer: Det vil sige, at du simpelthen får en efterregning.

Respondent: Ja.

Interviewer: Hvor tit sker det, at du får det eftersendt?

Respondent: Jamen det sker vel 5-10 gange om året. Noget af det vi har gjort de sidste 2-3 år er, at vi har pladser i Aarhus, Vejle, Odense og lige i Køge også, sådan at vi kan køre buffer-lager." (Kjelgaard 2020)

The respondent elaborated on the buffer warehouses AVAS has established in Aarhus, Vejle, Odense and Køge, and explained:

"Interviewer: Ah okay, so [because of the sites] you are not dependent on going all the way over there?

Respondent: Yes, a lot of things can happen on the road from here to Carlsberg Byen. But if we only have to go from Køge to Carlsberg Byen then you minimize the risk of failure.

Interviewer: What are your costs for renting these sites?

Respondent: Well, typically the cost is 150 kr per square meter yearly, for a raw site, and we probably have 12.000 square meters spread across the country.

Interviewer: So that is 1,8 million kroner. So this is actually costs caused by congestion.

Respondent: Yes, absolutely.

Interviewer: Am I understanding this correctly if is because the main motorway network is unstable?

Respondent: Very. You cannot cross Funen and expect anything else than delay. You cannot calculate whether it will take 5 quarters of an hour or 1,5 hours to get from Køge to the city center. It is just as expensive for us to be early because then we cannot utilize the day. We have those driving and resting hours which we have to take count of too.

Interviewer: That is exactly my next question; do you ever run out of resting hours?

Respondent: For resting hours? Of course, we do that every day. Then we have to stop there, reschedule and act on that. It is persons who plan this - not machines - they are not infallible.

Interviewer: What is the cause of running out; delays, clients? How much is caused by delays in traffic and how much is caused by delays from clients?

Respondent: This is a gut feeling - I cannot document how the distribution is - but I think 60% is caused by traffic, 35% by clients and 5% by persons, and by people I mean drivers and dispatchers. Well, we also have drivers who sometimes choose an alternative route and there won't be room for that.

Interviewer: So they receive the route they are meant to drive?

Respondent: Almost. If they are in doubt, it is discussed.

Interviewer: Okay. On an average day, how much driving-time do they have in spare in the end of the day?

Respondent: Well, those driving long distances have 15 minutes in spare out of the 9-10 hours. But surely it is experienced guys we have in there, so they are sharp at this." (Kjelgaard 2020)

"Interviewer: Ah okay, så [pga. pladserne] er I ikke afhængig af skulle hele vejen derover.

Respondent: Ja, der kan ske mange ting herfra og så over til Carlsberg byen, men hvis vi kun skal til Køge og til Carlsberg byen, så minimerer du risikoen for at det ikke lykkedes.

Interviewer: Hvad er jeres omkostninger for det I lejer der?

Respondent: Jamen de koster jo typisk 150kr pr. kvadratmeter om året, for sådan en rå plads, og vi har vel 12.000 kvadratmeter fordelt over landet.

Interviewer: Så der et 1,8 million. Så der er egentligt omkostninger, der kommer grundet trængsel.

Respondent: Ja, det er det absolut.

Interviewer: Er det rigtigt forstået, at det er fordi at hovedmotorvejsnettet er ustabilt?

Respondent: Meget. Du kan ikke køre over Fyn og forvente andet end forsinkelse. Du kan ikke beregne om det tager 5 kvarter at komme fra Køge og ind til centrum eller om det tager 1,5 time. Og det er lige så dyrt for os at komme for tidligt, for så kan vi ikke udnytte dagen. Vi har jo de der køre-hviletider, som vi skal ramme også.

Interviewer: Det er nemlig mit næste spørgsmål: Kører I nogen sinde tør?

Respondent: For kørehviletider? Det gør vi da, det gør vi hver dag. Altså så må vi stoppe der og planlægge om og gøre ved. Det er jo mennesker, der sidder og planlægger - det er jo ikke maskiner, de er jo ikke ufejlbarlige.

Interviewer: Hvad skyldes det, at I kører tør; er det forsinkelser, kunder? Hvor meget er forsinkelser i trafikken og hvor meget er forsinkelser fra kunder?

Respondent: Det bliver kun en mavefornemmelse - jeg kan ikke dokumentere hvad der er hvad - men jeg vil tro det er fordelt på 60% trafik og 35% kunder og så 5% på mennesker, og der mener jeg kørselsledere og chauffører. Altså vi har jo også somme tider nogle chauffører, der vælger en alternativ rute og det er der ikke plads til.

Interviewer: Så de får også ruten udstukket?

Respondent: Ej, næsten. Man taler om det, hvis man er i tvivl.

Interviewer: Ah okay. På en gennemsnitlig dag, for en normal chauffør, hvor meget kørselstid ender de så ud med i reserve.

Respondent: Jamen på dem, der kører mange kilometer, der har vi cirka 15 minutter ud af de 9-10 timer i reserve. Men det er klart, at det er nogle erfarne gutter vi har til at sidde derinde, så de er skarpe på det. ” (Kjelgaard 2020)

The important thing to note in the quote above is the fact that to avoid costs arising because of delays, AVAS has had to make investments in locations in or around the larger cities to have buffers that enable AVAS to be punctual in the case of events on the highways. As I shall return to in the discussion later, this is a very important finding, because it highlights that to understand the costs for logistics companies arising caused by delays, it is not enough to look at the trucks encountering

delays. It is also necessary to include the costs incurred by the logistics companies to make sure that their trucks does not become stuck in the delays in the first place. This cost is an example of one of these costs. Another example is what we encountered in the Schulstad example earlier, that Schulstad has invested in their trucks to make night-time delivery possible to avoid the peak-hour traffic.

A third type of costs associated with delays that became evident in the AVAS interview is the loss what we may call trust, or in more general terms, AVAS's brand-value to customers:

> *"Respondent: … In a firm like this, I have spent 20 years building a lot of goodwill by my customers, because I have also saved them when they have forgotten to place an order. To therefore I think there is a lot which is not visible.*
>
> *Interviewer: That is a great point.*
>
> *Respondent: Yes, and that is applicable for a lot of firms. DVS does not have this because that is business and according to contracts.*
>
> *Interviewer: It is corporate.*
>
> *Respondent: Yes, it is. But I'm close with my customers. I'm also available day and night, if they are really screwed. We also get calls on Sunday afternoons 'I forgot to place an order for tomorrow morning, can you help me?'. And that can be done, if another customer agrees to have the delivery on Monday forenoon, even though the customer was scheduled for 6.00 in the morning. So I call that customer on Sunday saying 'can I reschedule you for 10.00, Because we just had something coming up'. Then he shows me some goodwill by agreeing to change something we had already arranged. Because he has also tried to be the one calling in on a Sunday. And it is never measured by money. It's is measured by treating each other well.*
>
> *Interviewer: Even though it isn't apparent on the paper, then there is something which is affected by greater congestion. In the end the congestion delays begin to influence the goodwill more and more.*
>
> *Respondent: Sure, it always has a consequence, but it might not be exactly economic." (Kjelgaard 2020)*

> *"Respondent: ... sådan en butik som den her, der har jeg også gennem 20 år opbygget en masse goodwill ved mine kunder, fordi jeg også har reddet dem, når de har glemt at bestille. Så derfor tror jeg, at der er rigtig meget, der ikke er synligt.*
>
> *Interviewer: Det er en god pointe.*
>
> *Respondent Ja, og sådan er der rigtig mange butikker. Det har DSV ikke, fordi det er business og det er efter kontrakt.*

Interviewer: Det er corporate.

Respondent: Ja, det er det. Men jeg er jo tæt på mine kunder. Jeg er også tilgængelig døgnet rundt, hvis de virkelig er på den. Vi får også opringninger søndag eftermiddag "Jeg har glemt at bestille til i morgen tidlig, kan du hjælpe mig?". Og det kan så lade sig gøre, hvis en anden kan gå med til mandag formiddag, selvom de var sat på til. kl. 06 om morgenen, hvor jeg så ringer til ham der søndag, og siger, "hvis nu jeg kan rykke dig til kl 10? For vi har lige noget andet". Men så viser han mig noget goodwill ved at ændre noget vi havde aftalt. For han har selv prøvet at være den, der ringer søndag. Og den del bliver aldrig gjort op i penge. Den bliver gjort op i, at vi er ordentlige ved hinanden.

Interviewer: Selvom det ikke giver spor på papiret, så er der alligevel noget, der bliver påvirket med større trængsel. Til sidst så begynder det jo at tage mere og mere på den der goodwill.

Respondent: Jo jo, det har altid en konsekvens, men det er ikke sikkert, at den lige er økonomisk." (Kjelgaard 2020)

With these three further costs in mind, let us now turn to a 3PL, Vendelbo Spedition A/S.

4.4 Vendelbo Spedition A/S

Vendelbo Spedition A/S is a 3PL located in Hjørring north of the Limfjord in the middle of Vendsyssel. The main market of Vendelbo is Norway, i.e. transports to and from Norway, which account for around 75% of the turnover in the company. This includes transports between the European continent and Norway (Madsen 2020).

Vendelbo's operations is divided into three market segments. The first market segment is the Norwegian oil industry. In this market Vendelbo do not transport oil, but parts for the oil production and Vendelbo has a significant number of transports from Norway to the rest of the European continent and vice versa. The second market segment is food, and again the transports are both to and from Norway. Freight in this segment includes fish and refrigerated and frozen food products. The third market segment is general cargo, and this is the largest segment in Vendelbo's operation. In this segment one particular type of cargo stands out and that is kitchens and furniture. In this segment Vendelbo delivers directly to the end-user, i.e. the consumer.

The kitchen and furniture segment is organized so that Vendelbo collects the kitchens and furniture at the producers, typically in Denmark, and transports it to Vendelbo's terminal in Hjørring. At the terminal the kitchens and furniture are sorted onto trucks destined for Norway. These trucks travels to Norway by ferry and does the delivery trips in Norway delivering directly to the end-users, i.e. the consumers. To avoid empty driving on the return towards Denmark Vendelbo transports fish and wood from Norway towards Denmark. The rationality for this setup with only one terminal handling is to minimize the amount of cargo handling, which in relation to kitchens and furniture often result in damages to the freight. In more industry standard operations general cargo to Norway will go through two or more terminals, i.e. collection to terminal in Denmark – linehaul – terminal in Norway – delivery. Most general cargo is well suited to for typical setup with significant terminal handling, but kitchens and furniture is not. Therefore, Vendelbo has found a market niche here in which the company has grown tremendously in recent years, quote:

> *"Respondent: … what has become the biggest segment of this company is delivery of kitchens, tabletops and furniture to private customers, all the way to the end user. So that means the only repackaging of the goods is here at our site. Otherwise, we deliver to the consumer in Bodø, Tromsø, Finnmark or somewhere else. And it is purely to minimize the damages on the goods, so it does not have to be this terminal, terminal, terminal. It is good for some things, but there are also some things which it certainly isn't great for. So there we have found our niche, and it is growing. This segment of our company has been growing explosively the last few years." (Madsen 2020)*

> *"Respondent... Og det, der er blevet vores allerstørste segment i vores butik, er levering af køkkener, bordplader, møbler ud til private - helt ud til slutbrugeren. Så det vil sige, at det eneste ompakningssted er her hos os. Ellers leverer vi det direkte ud til en forbruger i Bodø, eller i Tromsø, eller i Finnmark et eller andet sted. Og det er simpelthen for at minimere skaderne på godset, så der ikke er det her terminal, terminal, terminal. Det er godt til nogle ting, men der er altså også nogle ting, som det absolut ikke er godt til, og der har vi ligesom fundet vores niche i*

det. Og den vokser. Det segment er vokset eksplosivt de sidste par år her i butikken." (Madsen 2020)

In the kitchen segment Vendelbo has integrated its operation closely with the producers to minimize handlings in relation to the transport as the following quote shows:

"Respondent: … Well, what we actually do, and this is special for the kitchens, is that we have our warehouse here, where we collect from 10-15 different producers. Then we pack it here and pack it into zones to optimize - because why send 5 trucks to the Finnmark if we can do it with 1 or 2 trucks which are completely full in that area. So we drive in small areas but with great volumes. And we do this for some of these kitchen manufacturers who get some things produced… one example is a kitchen manufacturer from Brønderslev, whom we drive a lot for. They have their tabletops produced in Mors. So instead of them picking up the tabletops from Mors so that they can pack it with the kitchens and ship the entire package, we pick up the tabletops and pack them with the kitchens here and ship it. It is a small thing which they have become very fond of." (Madsen 2020)

"Respondent: ... altså det vi egentligt gør - og det der er specielt med køkkenerne, det er det vi har vores lager til hernede - det er jo at vi samler ind fra 10-15 forskellige producenter, pakker det her og så pakker vi det i zoner for at optimere - det er jo ikke noget ved at få 5 biler i Finmarken, hvis vi kan nøjes med én eller to, der er fyldt helt op i det område. Så vil vi køre i små områder, men større volumener. Og så gør vi egentligt det for nogle af de her køkkenvirksomheder, der får produceret nogle ting… et eksempel er, at vi har en køkkenproducent her ved Brønderslev, som vi kører meget for. De får produceret deres bordplader ude på Mors. Så i stedet for at de henter deres bordplader fra Mors og pakke det sammen med køkkenerne, så henter vi dem ude på Mors, pakker dem sammen med køkkenerne her og sender dem afsted. Det er en lille ting, som egentligt de er blevet rigtig glade for." (Madsen 2020)

The delivery to consumers in Norway means that Vendelbo utilizes trucks that are able to cope with snow and that are well suited for delivery at home addresses. The fleet of vehicles Vendelbo utilizes for this therefore mainly consist of front-trailers with trailer or front-trailers with dolly and semi-trailer. This is different compared to the general tendency among 3PLs where most companies rely on tractor-semitrailer setups. Vendelbo owns and operates 37 trucks and collaborates with some 2PLs, so that in total Vendelbo employs 42 drivers and operates 50 trucks.

The cargo moved in the oil segment has similarities to general cargo, but according to Vendelbo the demands for fast delivery in this market segment means that it cannot be treated as general cargo:

"Respondent: No, well you can argue, that the oil business is general cargo, but it is not treated like general cargo, because often it has to be delivered so fast that we might only have few things with us. In the weekend we had a truck driving to England with only one tank which was only 3 meters long, because it has to get there quickly. And then you cannot fill it [the truck] with all kinds of stuff. Then it isn't general cargo anymore." (Madsen 2020)

"Respondent: Nej altså man kan sige, oliebranchen kan man også godt kalde stykgods, men det bliver ikke behandlet ligesom stykgods, fordi det tit og ofte skal køres så stærkt, at vi måske kun har få ting med. Vi havde en her i weekenden, som kørte til England med bare én tank, der var tre meter lang og det skulle bare gå stærkt. Og så kan man jo ikke fylde den (lastbilen) op med alt muligt. Så er det ikke stykgods længere." (Madsen 2020)

When looking at the costs of delays for Vendelbo Spedition, the costs firstly depend on the daily activity level in the company:

"Respondent: Well, sometimes you have plenty of time and sometimes you are under a lot of time pressure. And sometimes you end up being stuck in a queue or a traffic accident somewhere. Then we have to reschedule the program and simply turn things around, because we standing in a queue. So we have to joggle something because we cannot just keep driving." (Vendelbo)

"Respondent: Altså nogle er jo i god tid og ved andre er du helt vildt presset på tid. Og der er jo nogle gange, hvor man kommer til at holde i kø et eller andet sted eller hænger i ved en ulykke. Så er vi jo lige pludselig nødt til at lave programmet om og simpelthen vende tingene, fordi vi kommer til at holde i kø. Så er vi nødt til at jonglere et eller andet for vi kan jo ikke bare blive ved med at køre." (Madsen 2020)

Second, it also depends on the market segment. In the oil industry delivery on time is crucial as delays can generate extreme costs, for example idle time at oilrigs. This means that if oil transports are delays expensive countermeasures are sometime deployed. For example, if a truck is delayed and the driver is be unable to reach the destination due to his driving-time running out, one mitigation strategy may be to fly a new driver into position so that he can drive truck to the destination:

"Respondent: … Well, I have to say, as an example, if you drive with for the for the oil industry then you risk having to fly drivers into position. We have done that a few times, because the truck had gotten delayed due to traffic, and then you have to fly a driver to the position where he can take over the truck. But then of course we have to put that cost on the customer, so we call them and say ' if we have to get the goods there, then we have to do something extraordinary'.

Interviewer: But does it come up front or? So when you make the tender on the transport, do you count it in there or later?

Respondent: No, we make the tender from our calculations and experience that is will approximately take so and so long time. But sometimes it can go completely wrong.

Interviewer: But what if it goes completely wrong - I'm just curious - is it force majeure or what is it actually?

Respondent: No, well sometimes we will say so, but it is not often that we start to say force majeure, because we would call the customer and say listen, it is not ours fault, it is not your fault, it is nobodys fault, but we have been delayed due to an accident, and there might be some documentation of the accident, and if we are to keep the deadline we made, then we have to do

something extraordinary. And that is decided with the customer because they have to pay if we do. Unless we have screwed up completely, then of course we have to hanlde it." (Madsen 2020)

"Respondent: ... Altså jeg må sige, kører du terminsgods for eksempelvis olieindustrien, som det sommetider er, jamen så kan du risikere, at du skal flyve nogle folk i position, det har vi da gjort nogle gange ikke, hvor vi simpelthen er blevet så forsinkede på grund af trafik, at man er nødt til at flyve en chaufför et sted hen, som så kan overtage bilen. Men det er jo så klart, at den omkostning er vi nødt til at lægge på afsenderen, og sige, hvis vi skal have den her frem, så er vi nødt til at gøre noget, så skal der gøres noget ekstraordinært.

Interviewer: Men kommer den up front eller? Altså er det når nu du giver et tilbud på transporten du regner det her ind, eller er det?

Respondent: Nej, så regner vi ind, sådan efter vores erfaringer, at det tager cirka så og så lang tid. Men det kan jo gå helt galt nogle gange.

Interviewer: Men hvis det går helt galt - jeg er bare nysgerrig på - er det force majeure eller havd er det egentlig?

Respondent: Nej, altså, altså vi vil jo påpege, det er jo ikke så tit at vi begynder at påberåbe os force majeure, fordi vi ville jo ringe til kunden og sige, prøv at hør her, vi kan ikke gøre for det og I kan ikke gøre for det, altså der er jo ikke nogen, der er skyld i det her, men hvis vi skal overholde den termin som vi har sagt, altså vi er blevet forsinket pga. af den her ulykke, så er der måske noget dokumentation ikke at vi er der, og så afgør vi det jo sammen med kunden om der skal gøres noget ekstraordinært, for de skal jo selvfølgelig også betale for det, hvis vi skal gøre noget ekstraordinært. Med mindre det er os, der har bommet fuldstændig i det, så må vi jo stå på mål for det." (Madsen 2020)

The respondent elaborated:

"Respondent: Yes, we have tried a few times, where we were delayed because of traffic or unfortunate circumstances, where we have flown a driver. Actually he was going the other way, we have done that even more times, where we have flown a driver down to Frankfurt or Munich, so we had a driver to drive home. Again, it is all about due care. Does it work or is something about to slip, if so we have take action. And it sounds crazy, but before the Corona-crisis a plane ticket did not cost a lot of money. We have also had some cases where it has been planned, where we put a driver on the truck and an extra driver onboard, that happens…

… If we make such an urgent transport, then we have two drivers in the truck right from the beginning. Then it has to be very extreme, if we need to have someone in position also. It has happened that two drivers have driven as far as they could. Then we have said 'position an extra driver and then we have flown someone in position in Bordeaux or somewhere else. Then he take over the truck and the two others just stay at a hotel before returning home. It has also happened, but again only if they start to measure the delay in hours, no not the delay, but what the

cost per hours is to have a ship in a harbor or downtime at a drilling rig. Then the cost is nothing [with the truck], it means nothing." (Madsen 2020)

"Respondent: Ja, vi har da prøvet nogle gange, hvor vi er blevet forsinkede simpelthen på grund af hvad skal man sige, trafik eller uheldige omstændigheder, så har vi fløjet en, det var faktisk en der skulle den anden vej, det har vi gjort flere gange, hvor man har fløjet en ned til Frankfurt eller til München og så havde en chauffør til at køre hjem. Det er jo igen det med rettidig omhu. Duer det her eller er det ved at skride, så gør vi noget. Og det lyder jo helt vildt også, men før Corona-krisen, der kostede flybilletter jo ikke alverden. Vi har også haft nogen, hvor vi har, altså hvor det har været kalkuleret ikke, hvor vi sætter chauffør på, og så ekstra (chauffør). Det sker jo…

… Hvis vi endelige laver sådan en haster der, så har vi to chauffører med til at starte. Så skal det være helt ekstremt, hvis vi skal til at have en i position. Det er da også sket, at der er to chaufførers, der har kørt så langt som de kunne. Så har man sagt, "ind med dem" og så har vi haft fløjet en i position i Bordeaux eller et eller andet, hvor man så siger, at han tager over og de to andre bliver bare på hotellet og så hjem igen. Det er også sket, men det er igen også det der med, hvis de begynder at gøre op med at forsinkelsen i tid, nej ikke forsinkelsen, men hvad koster det i timen at have måske et skib liggende i havn eller en boreplatform der står stille. Så de der, det håndører det koster [med lastbile], det betyder ingenting." (Madsen 2020)

Unsurprisingly the situation is different in the segment focused on transport of kitchens and furniture. In relations to delays in the segment the respondent explained:

Respondent: You just inform. The delays we have had when driving to Norway and Sweden with kitchens are rarely due to traffic, it's more often the ferry that is cancelled due to storms. Or it might be because of snow and ice. So it is more due to accessibility and there is great comprehensibility for such matters in Norway and Sweden. In such cases we just send a message that unfortunately we will be delayed. So the set-up is completely different. Some might be a little grumpy not receiving their kitchen on a certain date, but it is also annoying not to receive it on the day expected. But if it is because of storm and you cannot get there, then you have to understand the cause. We are not delayed because the drivers have been picking their nose and people have a greater understanding for that the further North you travel in Norway. That's how it is." (Madsen 2020)

"Respondent: Der melder man jo bare ud. De forsinkelser, som vi har haft, når vi kører til Norge og Sverige med køkkener, der er kap så trafikalt, altså det er typisk færgeforsinkelser, hvor de indstiller færger på grund af storm. Eller også så er det på grund af sne og is. Så fremkommelighed kan man kalde det - og det er der fuld forståelighed for i Norge og Sverige. Der skriver vi bare, at vi desværre bliver forsinket. Så det er jo et helt andet set up. Der kan godt være nogen, som bliver lidt sure over, at de ikke får deres køkkener den dag, men altså, det er også træls at man ikke får det den dag, man regnede med at det skulle ind, men hvis det er fordi at det stormer og man ikke kan komme over, så er man også nødt til at forstå at der er en årsag til det. Det er jo ikke fordi vi har siddet og pillet næse vel - det ved folk også og jo længere du kommer op i Norge, jo mere forståelse er der for forsinkelser. Sådan er det." (Madsen 2020)

In relation to delays in the general cargo transport we have to look at the daily operation rhythm to understand how the Limfjord Tunnel impacts Vendelbo's operation in this segment:

> *"Respondent: Well, the daily rhythm is that we have trucks driving south now [afternoon]. They are typically in place tomorrow morning at Sealand, or Southern Jutland or Padborg. Then they will be ready to load tomorrow where they collect goods from Jutland, and the trucks from Sealand collect goods from Fyn, Jutland and further north. Then they arrive here at 18.00 and it is all turned around. We might have 5-8 trucks coming up here, then the freight is sorted and 5-8 trucks drive from here to the ferry in Hirtshals or Frederikshavn. So that is the way in which we work. Then of course we also have goods being delivered here from the trucks which are going the other way." (Madsen 2020)*

> *"Respondent: Jamen altså døgnrytmen er egentligt, at vi har biler kører ned af nu [eftermiddag]. De står typisk på Sjælland i morgen tidlig eller i Sønderjylland og Padborg. Så er de klar til at læsse op i morgen, hvor de henter gods ind i Jylland, og dem fra Sjælland, de henter på Fyn og Jylland og opad. Så kommer de herop til omkring ved 18-tiden og så bliver det lige vendt rundt. Der går måske 5-8 biler op og så bliver det mikset rundt, og så kører der 5-8 biler herfra op og med færgen fra Hirtshals eller Frederikshavn. Så det er jo egentligt den måde vi arbejder på. Så kommer der jo også noget den anden vej." (Madsen 2020)*

This operation makes delays on the trips to Hjørring along the E45 highway in East-Jutland and through the Limfjord Tunnel in the afternoon and evening critical, because if the freight is delayed to Hjørring, then the sorting is also delayed, and potentially it becomes impossible for the trucks departing to Norway to reach the ferries on time:

> *"Interviewer: With that planning. Does that mean, that you get everything [accidents] that happens up along E45?*

> *Repsondent: Well, sometimes when it goes wrong up here, then we have to come up with an emergency plan in the last minute. Last week we had one whom should have been on the ferry across by Kristianssand, but because of traffic we had to send him through Larvik because he was too late. That is just how the traffic is. It can also be customers who are delayed or a driver who has miscalculated his resting time and so on. It can easily just be things like that. But in this case it was traffic, and it does have a cost and you cannot just pass on the bill.*

> *Interviewer: This planning going North; how big do the delays have to be before it starts to be problematic for you?*

> *Respondent: It depends. We always have a natural buffer of 30 to 60 minutes. Generally, it starts to be critical when we have downtime for more than an hour. Luckily, it is not often that it happens. It is relative quick, but surely, every minute principally counts.*

> *Interviewer: Sure, but as long as it is within a certain timeframe then you can deal with it.*

Respondent: But when it exceeds that time limit then it starts to be critical. Especially because it isn't just one truck which is delayed - it is all of them. They will all be stuck in the same queue and then we can have 4-5-6 trucks in the same traffic queue in Aalborg.

Interviewer: I also think that given that you load the truck here, then they have to be packed and ready. Then it is no use that you are one truck short, because then you are lacking the goods from that truck.

Respondent: The last truck might have goods for 5 other trucks. So sometimes you have to make a decision whether to wait for the last one or to drive the route with unused space in the truck. Then it is just bad luck that the last goods didn't make it. But it is a prompt decision made by the dispatchers." (Madsen 2020)

"Interviewer: Men den rytme. Vil det så sige, at I får alt [uheldene] hvad der sker op af E45?

Respondent: Jamen, der er nogle gange, hvor det går helt galt heroppe jo, og så er vi nødt til at lave en feberredning i sidste øjeblik. Sidste uge havde vi en, som skulle have været med ud over Kristiansand, men på grund af trafik måtte vi sende via Larvik, fordi at han kom for sent. Det er bare sådan trafikken er. Det kan også være kunder der er forsinkede eller en chauffør, der har regnet forkert på hans pauser og så videre, det kan også være sådan nogle ting. Men her var det trafik, og det koster nogle penge og det kan du ikke bare sende regningen videre for.

Interviewer: Den her rytme opad, hvor store skal forsinkelserne være op ad før de begynder at ramme jer?

Respondent: Det kommer lidt an på, man sige, der er altid bygget sådan en naturlig buffer ind på en halv time til en time. Man kan sige, det begynder at blive kriminelt at vi står stille i mere end en time oftest. Det er jo heldigvis ikke så tit de gør det. Der er sådan en forholdsvist hurtig, men det er jo klart, at hvert minut tæller i princippet.

Interviewer: Det er jo klart, men så længe det er indenfor noget, som man kan håndtere.

Respondent: Men når det begynder at komme derudover, så begynder det også at blive kriminelt heroppe. Specielt, altså det er jo alle biler, det er jo ikke kun én bil, der kommer til at hænge. Det er jo den samme kø de holder i alle sammen, så vi kan have både 4-5-6, der står i den samme kø ude i Aalborg.

Interviewer: Jen tænker også, at i og med at I netop laster op herop, så skal de også være pakkede og parate, så duer et jo heller ikke, at I mangler en, fordi så mangler i.

Respondent: Han kan jo have til 5 biler ham den sidste der kommer. Så nogle gange er man tage en beslutning og sige, er det noget vi skal vente på, eller skal vi køre ud med plads tilbage i bilen, så det var ærgerligt, det kom ikke med. Det er jo en beslutning som skal tages af disponenterne lynhurtigt." (Madsen 2020)

Asked about the costs associated with the delays the respondent explained:

> *"Respondent: That is the problem, to get the bill passed on according to whose fault it is. It is not the manufacturer's fault that they are placed south of the fjord. But this is a huge problem. If you talk with the ferry companies, then they fear a huge accident will take place where an tank truck is overturned in the tunnel, god forbid it, but if this happens and it is closed for a few months. It would have immeasurable consequences for both us and especially the ferry companies. Just think of all the cars which should have been on the ferries. I have heard about how many hundred thousand trucks that passes the port of Hirtshals each year, and the number is not small. And even though some argue that nothing happens on these highways up here, then something must drive here anyway." (Madsen 2020)*

> *"Respondent: Det der er problemet, det er at få den regning sendt videre, for hvis skyld er det. Det er jo ikke producenternes skyld nede i landet, at de ikke bor nord for fjorden. Men det er et kæmpe problem det der. Hvis du snakker med rederierne, så frygter de jo, hvis der sker en stor ulykke, hvor der er en tankbil, der vælter ude i tunnellen ikke - guderne forbyde det ikke - men hvis det sker og det er lukket i et par måneder. Det ville jo få uoverskuelige konsekvenser for både os men specielt også for rederierne. Bare tænk på alle de biler, der skulle være med færgerne. Jeg har hørt om hvor mange hundredetusinde lastbiler, der passerer i Hirtshalshavn om året, det er altså ikke småafdelingen. Og selv om man siger, at der ikke foregår en skid på de her motorveje, der må jo bare køre nogle her på et tidspunkt." (Madsen 2020)*

The situation with Vendelbo's trucks being stuck at the Limfjords Tunnel is not a rare occasion, as the following quote shows:

> *"Respondent: Well, I talked with one not very long time ago in another context. He worked in Nørresundby and lived in Støvring and then he says 'well I know your company because I see your trucks in the queue at the tunnel. Because I see your trucks in the queue every single afternoon when I drive home from work'. And that explains very well that we are stuck in the congestion when we arrive at these rush hours and it happens almost every day. And it might have a cost… if we have approximately 10 cars driving North through the tunnel every afternoon then we lose maybe 2-3 hours of disposal time or work, right. And then you can start to add up on a yearly basis. It is a lot of money." (Madsen 2020)*

> *"Respondent: Jamen altså, jeg snakkede med en for ikke så længe siden i en helt anden forbindelse. Han arbejder i Nørresundby og boede i Støvring og så siger han så "Jamen jeg kender godt jeres firma, for jeg ser jeres biler, holde i kø ude ved tunnellen. For jeg ser en af jeres biler holde i kø derude hver eneste eftermiddag, når jeg kører hjem fra arbejde". Og det siger jo egentligt meget godt et eller andet om, at vi står stille derude, når vi kommer på de her spidsbelastningstidspunkter og det er jo stort set hver dag. Og det koster måske… hvis vi har, hvad har vi, måske 10 biler der kommer op hver dag, der hen ad eftermiddagen, så mister vi måske 2-3 timers rådighedstid eller arbejde, ikke. Og så kan du begynde at gange op på det for året. Det bliver mange penge." (Madsen 2020)*

In the planning of the trip normal congestion delays are included as illustrated by the quote below:

"Interviewer: Now, I know that you drive in various areas, but if you talk about the oil business then it is focus on time. In relation to the example of one single tank going to England. If you take that example, then what is the cost for you? Can you try to elaborate on that or explain how it affects your operation?

Respondent: Well, we try to think things through. We know there is congestion out there [at the motorway through the tunnel] in the afternoon when they drive this way. It is things like that which we learn. We also know there is congestion every morning when driving into Antwerp for example. And it is a cost to us from the moment the truck isn't moving because the driving resting time hours have to be kept. You get a pretty tough punishment if you exceed the limit of the resting hours. When you are stuck on the motorway you are not resting. It is still driving time, it is just moving slowly. You might drive 1 kilometer or a few kilometers per hour, so you can say that that is the cost. Time and money… then you can add up how many hours we are dealing with on average each day.

Interviewer: Do you add time for that?

Respondent: Yes, sometimes we do. The dispatchers do, they know that if you arrive at Aalborg between 16.00 and 17.00 then you have to add another 30 minutes every day.

Interviewer: Who takes the cost of those extra 30 minutes?

Respondent: We do." (Madsen 2020)

"Interviewer: Nu ved jeg godt, at I kører forskellige områder, men hvis du tager oliebranchen den er tidsbestemt - i forhold til det med én tank, der skal til England. Hvis man tager det som eksempel, hvad koster det så jer? Kan du prøve at uddybe det eller forklare hvordan det påvirker jeres operation.

Respondent: Jamen altså vi tænker tingene ind. Vi ved jo at der er kø derude [motorvejen ved tunnellen] om eftermiddagen, når de kommer den her vej. Det er jo sådan noget vi lærer. Vi ved også at der er kø indtil Antwerpen om morgenen for eksempel. Og det koster jo nogle penge lige så snart det står stille på chaufføren, fordi vi har nogle køre-hviletidsregler, som skal overholdes. Der bliver man jo straffet temmelig hårdt, hvis det er, at man overskrider dem. Når man holder stille på motorvejen, så holder man jo ikke pause. Det er stadig køretid - det går bare langsomt. Du kører måske 1km eller et par km på en time, så man kan sige, at det som det koster. Det er at det koster tid. Tid og penge… så kan man gange op på hvor mange timer det handler om i gennemsnit om dagen.

Interviewer: Lægger I ekstra tid ind til det?

Respondent: Ja det gør vi nogle gange. Altså det gør disponenterne, de ved jo godt, at hvis du kommer til Aalborg mellem kl. 16 og 17, så skal du lægge 30 min til hver dag.

Interviewer: Hvem tager regningen for den halve time?

Respondent: Den tager vi." (Madsen 2020)

Asked about how to quantify the costs the respondent replied:

"Respondent: It is very, very hard to say generally. There are both direct and indirect cost which can occur. What I mean by this is that this is a house of cards, and if something starts to fall then it all falls down very fast. Only rarely you manage to save part of the house and then we have to take a deep dive into what the cost is for 1 hour downtime and what the cost in production time will be if we are late for the ferry. We lose a lot of money each year at expense of this, I have no doubts about that at all, but I almost do not dare to start calculating the cost. We cannot do anything about it. We try constantly to deal with it through the price determination but the margin in our business is very small as it is already. If you take a look at the big companies like FREJA and what their earnings are, then I think we are almost on the same wavelength. Of course, they have significantly higher earnings than us, but we also have a significantly smaller turnover, but it is not really that, it is more that you set the price as high as the market can support it. It is supply and deman of the worst sort, because transport is something that everyone wants to make savings on. That is the easy thing to make saving on, there are at least some of these kitchen producers that have found that transport can be an extremely dangerous place to save for them. It is important to have specialized logistics solutions instead of just running it terminal terminal.

Interviewer: Now, I look at this from an outside perspective, but I think that it sounds like a race to the bottom in regard to the price.

Respondent: Yes, that is what we were trying to stop. We have decided not to be part of that race. If you knew how many times we have been told that our price is too high where I think, lovely, then I know we have calculated the price right. We want to offer a product which takes CSR and environment into consideration. We have no old trucks driving around, but the new technology everybody talks about, it is not available for us yet, long-haul. It does not exist yet but when it does, we will use it. But right now we do not have any of it. We have stated that we do not want to go down the road where price is the only thing on the agenda. We would rather say service, service, service. The clients should put forward their criteria or demands and then look at the solutions as a whole. What we have discovered with quite a few of our customers is that if they instead of just looking at their transport budget took a wider look, then it could save their firm money if they use extra money on transport instead of choosing the cheapest hauler. It might be the most expensive hauler which is the best for the company seen in the long run. This is what we have seen, and I can mention multiple examples where people say damn, it is actually true what you say. And then we said that we want to ensure that our drivers work with the right salary and pension and that the trucks are proper and that the drives behave good when they are out. So we can say, that we take care of matters in this business and therefore they can trust there is no child employment or underpaid workers. We have CSR under control, right. And there are a lot whom like Lord Nelson puts the binocular to the blind eye on this issue. [Company-name A] - not because we have to expose them in some way - but they had properly made a deal

with [Company-name B] and [Company-name B] had a deal with [Company-name C]. [Company-name A] and [Company-name B] probably both had someone to sign that things were ok. But they were not at that appeared further down the chain at [Company-name C]. Why do you do such thing? You do it because you want the [Cargo type] transported as cheap as possible." (Madsen 2020)

"Respondent: Det er meget, meget svært at sige generelt. Der er jo både de direkte og indirekte omkostninger, der kan komme og det jeg mener med det her, er jo, at det er sådan et korthus der står og begynder noget af det hele at vælte, så vælter det hele og det sker lynhurtigt. Det er sjældent, at man når at redde noget af korthuset og så skal vi jo til at dykke ned i hvad det koster at stå en time der og hvad det koster at komme for sent til færgen i produktionstid. Vi mister mange penge hvert år på den bekostning - det er jeg slet ikke i tvivl om - men jeg tør næsten ikke tænkte på at begynde at regne på det. Det er jo ikke noget som jeg kan gøre noget ved. Vi prøver jo hele tiden at prissætte os ud af det for marginen i vores branche er i forvejen meget små. Hvis man ser i forhold til de store som Freja og hvor meget de tjener på deres - så tror jeg vi lægger meget på bølgelængde på dem. De tjener selvfølgelig væsentligt flere penge end vi gør, men vi omsætter også væsentligt mindre, men det er jo egentligt ikke det, men det er igen det med at du prissætter lige så højt, som markedet kan bære. Det er udbud og efterspørgsel af værste skuffe og det er meget følsomt, for transport, det er sådan noget, som alle de gerne vil spare på. Det er det nemme at spare på - det er der i hvert fald nogen af de der køkkenfirmaer, der har fundet ud af at det kan være utrolig farligt at spare der for dem. Det er jo vigtigt at de har en specialiseret logistikløsning i stedet for bare noget der kører terminal, terminal.

Interviewer: Nu ser jeg jo på det udefra, men jeg synes det lyder meget som sådan noget race to the bottom med prisen.

Respondent: Jo, det var ligesom det vi prøvede at stoppe. Vi har ligesom sagt, at vi ikke vil være med på den der. Hvis du vidste, hvor mange gange vi har fået at vide, at vi er for dyre, så havde jeg tænkt, at "det var da dejligt, for så ved vi at vi har regnet rigtigt". Vi vil gerne levere et produkt, hvor der er styr på CSR og miljø. Vi har ingen gamle biler der tøffer, men den nye teknologi alle de snakker om - den er ikke til stede for os endnu for den type transport - longhaul - men den findes ikke endnu, men når den kommer, så skal vi også bruge den. Men lige nu har vi ikke noget. Vi har ligesom sagt, at vi ikke vil ned ad den der sti, hvor man kun tænker på pris, pris, pris. Vi vil hellere sige service, service, service. Opstil nu jeres kriterier eller krav og så kig på det som en helhed. Der har vi opdaget ved en del kunder, at hvis de i stedet for bare at kigge på deres lille logistik budget, men kiggede lidt bredere, så kunne det være de kunne spare deres virksomhed ved faktisk at bruge nogle flere penge på den transportør i stedet for at vælge den billigste. Den kan jo godt ske at den dyreste han er den bedste for virksomheden på den lange bane. Det har vi set og jeg kan nævne flere eksempler på det, hvor der er nogen, der siger "hold da kæft, det er faktisk rigtigt det du siger" og så har vi ligesom sagt, at vi gerne vil sørge for at vores chaufførerfår det de skal have i løn og pension og at de kører nogle ordentlige biler og opfører sig ordentligt når de er ude - så kan vi sige, at vi arbejder med tingene her, så I kan trygt stole på, at der ikke er nogen børnearbejdere her eller nogen, som er underbetalt her på den konto. CSR'en er der styr på ikke - der er rigtig mange, ligesom Lord Nelson, som sætter kikkerten for det blinde øje. [Company-name A] - ikke fordi vi skal sidde og udlevere dem - men de havde jo helt sikket lavet

en aftale med (Company-name B) og [Company-name B] havde lavet en aftale med [Company-name C]. [Company-name A] og [Company-name B] har da begge to fået nogen til at skrive under på, at der er orden på tingene. Men der er ikke orden på tingene, det kunne man se længere nede, at [Company-name C] ikke havde orden på tingene. Hvorfor gør man det? Det gør man fordi man vil have kørt [Cargo type] så billigt som muligt." (Madsen 2020)

As we have also seen earlier in the other cases, it is difficult to estimate the costs of delays, as it depends on how busy the company is the given day, the characteristics of the transport, and some are tangible costs and other are more difficult to quantify for example trust and reputation as we saw in the AVAS case. As has been discussed before, Vendelbo often encounters problems with trucks being stuck heading north on route to the terminal in Hjørring. Asked about what a new connection across the Limfjord would mean to Vendelbo the respondent replied:

"Respondent: Well, there is no doubt that is would offer some kind of security. Take me, I am afraid something will happen. I do not shake from fear every day, but it is in the back of my mind. And every time we discuss how vulnerable we in fact are by having our business up here. I do not think that it is something which makes you say hurray now I want run a company in Vendsyssel, because it is just so great. Because exactly if a big accident takes place, now we saw that time they sailed into the railroad bridge. I took 1,5 year before it was up and running again. Now, I'm not saying, it would probably be more difficult to sail into the tunnel. But something could happen. There could also be a moron thinking he has to play with ammonium nitrate in the tunnel or something like that. We don't know… I do not think the Aggersund Bridge can handle the pressure and neither can Hals-Egense. But it would provide some kind of security by having another option for transport if something goes wrong in one place. It is decisive for us in this region.

Interviewer: The risk which you live with today, what could you save? If I can ask like that… Could you have fewer drivers on standby?

Respondent: There is no doubt that we could optimize the business I bit more. Optimize on material and maybe not so much in regard to people. We need people all the time. If you knew how many times we drive to pick up someone in the Store Vildmose because they are out of driving time due to congestion in the tunnel, which made them run out of driving time. Then we have to send a driver to get them, because we cannot just let them stay there until tomorrow morning, right. So we have so send a man there. It happens every week." (Madsen 2020)

"Respondent: Jamen, der er da ingen tvivl om, at det ville give en sikkerhed. Altså jeg er da bange for, at der sker noget. Jeg går da ikke sådan og ryster hver dag, men det ligger da i baghovedet. Og hver gang vi diskuterer det, hvor sårbare vi egentligt er ved at have en virksomhed heroppe. Men jeg synes jo ikke ligefrem, det der gør, at man siger jubii nu vil jeg drive virksomhed i Vendsyssel, for det er bare så fedt. For netop hvis der sker en stor ulykke, nu så vi dengang de sejlede på jernbanen. Der gik jo halvanden år, før det var oppe og køre igen. Nu siger jeg, ikke, det er nok sværere at sejle på en tunnel ikke. Der kunne ske et eller andet. Der kunne også være en eller anden tosse, der synes, at han skal lege med ammoniumnitrat dernede eller sådan noget. Altså vi ved jo ikke… jeg tror ikke Aggersundbroen den kan klare presset, og heller ikke Hals-Egense

vel. Men det vil give en eller anden sikkerhed for at, det der med at have en option på at vi kan noget andet, hvis det går galt det ene sted. Det er da helt afgørende for os fra egnen her.

Interviewer: Den risiko du lever med i dag, hvad kunne du spare, hvis man kan sige det sådan. Kunne du have færre chaufførerpå standby, kunne du have,

Respondent: Der er da ingen tvivl om, at vi kunne godt lige give optimeringsgraden en tand opad. Optimere sådan materielt og knapt så mange folk. Vi skal jo hele tiden have folk, altså hvis du vidste hvor mange gang vi kører ud for at hente nogen ude i vildmosen herude bare fordi de ikke har køretid, det er fordi de har holdt i kø i tunnellen, så har de ikke mere køretid. Så er vi jo nødt til at køre ned og hente dem, for vi kan jo ikke have dem holdende dernede til i morgen, vel. Så er vi nødt til at sende en mand ned for at hente dem. Det sker hver uge." (Madsen 2020)

The respondent elaborated on the issue of picking up drivers that had run out of driving time:

"Respondent: It is because they sit. We optimize all the time, so we drive right to the limit all the time and preferably we shouldn't exceed the limit. So we sit all the time and have to make sure everything is in place. And then they might be waiting too long by a customer and then the driver is out of driving time. He might have other plans when he gets back here, so then he might have 10-15 minutes. So if you are waiting out there for 45 minutes, then the driver is 30 minutes short and those 30 minutes cannot just be found somewhere else. You can't just drive for an extra 30 minutes today 'because I just have to get home and then I'll drive 30 minutes less tomorrow'. That's not how it works." (Madsen 2020)

"Respondent: Det er jo fordi, at de sidder. Vi optimerer jo, så vi kører til grænsen hele tiden og vi må helst ikke komme over grænsen. Så vi sidder jo hele tiden og skal have det sidst med. Og så kan de holde ude ved en kunde og vente lidt for længe, så har chaufføren ikke mere køretid. Han har måske planer, når han kommer herop, så har han måske 10-15 minutter. Hvis du så holder derude i 45 minutter, så mangler der lige pludselig 30 minutter og du kan jo ikke trylle 30 minutter. Du kan jo ikke bare sige, at nu kører jeg 30 minutter ekstra i dag, for jeg skal bare lige hjem, og så kører jeg 30 minutter mindre i morgen. Sådan fungerer det ikke." (Madsen 2020)

This raises a natural question about how much slack the driving-time plans contains to accommodate delays, to which the respondent explained:

"Respondent: We normally work with 1 hour [slack]. But again, things happen all the time and it can just as well be the customers as the traffic. Sometimes you arrive at a customer and they tell you, oh we aren't completely done yet. Then you wait for them to finish loading another truck. There can be thousands of things which are always unknown." (Madsen 2020)

"Respondent: Vi plejer at sige 1 time [slack]. Men igen, der sker ting hele tiden og det kan jo ligeså nemt være kunderne den er galt med, som det kan være trafikken. Hvor du kommer ud til en kunde som siger, agh vi er altså ikke helt færdige. Så holder du lige og venter på, at de skal være færdige med at læsse en anden. Der kan jo være tusinde ting, der er jo hele tiden ubekendte." (Madsen 2020)

This also corresponds to what we saw in the AVAS case, where the respondent mentioned different types of delays, some caused by traffic, some by customers, and some by mistakes and drivers taking alternative routes.

Asked about the costs of picking up a driver another issue emerged, which is the difference between running out of driving time before a break and running completely out of driving time or availability time (rådighedstid). The respondent explained:

> *"Respondent: … if you take a day then the driving time is 2 times 4,5 hours - 9 hours in total - and some days you are allowed to drive for 10 hours - 2-3 days a week I think. But disposal time means that if you start at 6.00 somewhere then you have 13 hours to conduct your driving time or your working time. So at 19.00 you should start your rest because you have to rest for 11 hours to make it within 24 hours." (Madsen 2020)*

> *"Respondent: ... hvis du tager et døgn, så er køretiden de 2 gange 4 1/2 time - det er 9 timer - og nogen dage må du så køre 10 timer - to eller tre dage tror jeg. Men rådighedstid betyder, at hvis du starter kl. 06:00 et eller andet sted, så har du 13 timer til at afvikle din køretid eller din arbejdstid, så kl. 19:00, der skal du påbegynde dit hvil, for du skal jo holde 11 timers hvil for at kunne nå at gøre det indenfor 24 timer." (Madsen 2020)*

If a driver runs out of driving time and needs to take a break, then Vendelbo will send a "new driver" in a van to meet the "stuck driver". The "new driver" will then take the truck and drive home, and the "stuck driver" will wait in the van until he can drive agan, and then return to Vendelbo in the Van. The more expensive an troublesome situation emerges if the driver has used up his 9 or 10 hours of driving time, or is running out of availability time, i.e. have been active 13 hours. In this case the driver is not allowed to drive anymore that day, and in these cases Vendelbo sends a car with two new drivers. One new driver will drive the truck to Vendelbo, and the other new driver will drive the car with the "stuck driver" as a passenger.

Picking up drivers like this generate extra costs, in the form or one or two extra driver salaries for the time spent on the task. The situation occurs every week, and actually Vendelbo has three retired drivers employed that collecting stuck drivers and trucks when this situation occurs. This is a clear example of extra costs associated with the delays in the Limfjord Tunnel. Also, it should be added, that depending on where the driver becomes stuck, paperwork might also be needed is the driver is stuck on the highway and needs to break driving hour regulation to exit the highway:

> *"Respondent: Well, it depends completely on whether the queue is so heavy that you cannot change anywhere. Because then it is a violation because you cannot change drivers on the motorway. Then you are making a violation. Then you take the next exit and change drivers. It might happen that we violate the law, but then you make a transcript and write that you were stuck in traffic, and that is not a problem today. It was back in the days, back then you could get a fine for it. Back then you should be able to foresee that you would be stuck in traffic, luckily it is not like that anymore." (Madsen 2020)*

> *"Respondent: Altså, det kommer jo helt an på om køen er så voldsom, at du ikke kan komme til at bytte nogen steder, så er du jo ude i at lave en overtrædelse, for du kan jo ikke skifte chaufføør ude på motorvejen. Så laver du jo en overtrædelse. Så kører du af på den nærmeste afkørsel og så bytter du der. Der kan det da godt ske, at vi bliver lovbrydere, men så laver man en udskrift og skriver, at man har holdt i kø - og der er ikke noget problem i dag, det var det i gamle dage, der kunne du godt få en bøde for det. Der burde du kunne forudse, at du kommer til at holde stille, men sådan er de heldigvis ikke længere" (Madsen 2020)*

This is, as we shall return to later what we may term an issue of costs "after the road". Let us now turn to Danske Fragtmænd A/S.

4.5 Danske Fragtmænd

Danske Fragtmænd is one of the large logistics companies in Denmark, and the organization is shown in figure 1.

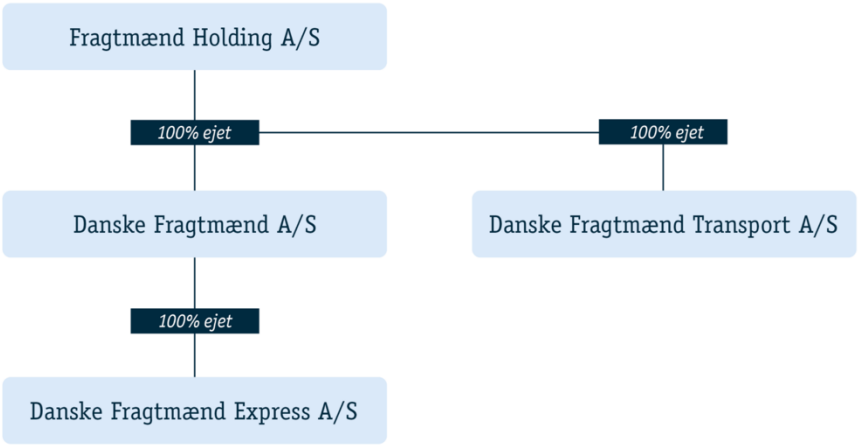

Figure 1: The figure shows the organization of Danske Fragtmænd (Danske Fragtmaend 2020)

Danske Fragtmænd A/S is handling the transports that goes through the terminals and Danske Fragtmænd Transport A/S handles the direct transports, i.e. truckload and less-than-truckload (LTL) transports that do not go through the terminals. To understand the impacts of the delays upon Danske Fragtmænd four persons were interviewed: CIO Ulf Preisler who has a detailed understanding of the overall operation. Jørgen Kannik who is the CEO of Jørgen Kannik A/S which is one of the transport companies Danske Fragtmænd A/S uses for its terminal transports. Given the history of Danske Fragtmænd which goes back to the time in which freight transport was a monopoly in Denmark, the company structure in Danske Fragtmænd A/S is a bit complicated. Shortly explained, Danske Fragtmænd A/S uses a number of subcontractors in the form of transport companies which are branded as Danske Fragtmænd A/S, and these transport companies also own shares of the stocks in Danske Fragtmænd Holding A/S. To understand the impact on direct transports Kenneth Jespersen who is Division CEO in Danske Fragtmænd Transport A/S and Søren Køpke who is Chief Dispatcher in Danske Fragtmænd Transport A/S were interviewed. As a follow up on the interviews Terminal CEO Bo Kristensen at Danske Fragtmænds terminal in Aalborg was asked a few questions also regarding the terminal operation.

To understand how events in the tunnel influences the operations by Danske Fragtmænd let us start locally near the Limfjord Tunnel by Jørgen Kannik A/S who is located at Danske Fragtmænd A/Ss terminal in Aalborg East. The Danske Fragtmænd A/S terminal in Aalborg is located at the port east of the city, south of the Limfjord and east of the Limjord Tunnel. The terminal operation of Danske Fragtmænd is organized so that line-haul trucks drive between the terminals at night, and during the day freight is distributed from and collected to the terminals. There are also other segments such as direct full load and Less-than-truckload, crane, express and night-delivery, but looking at the largest part of the operation, this is what comes through the terminals. Jørgen Kannik delivers freight from the terminal in Aalborg, and collect freight to the terminal, in the postal codes 9000-

9230, i.e. Aalborg and the surroundings south of the Limfjord from Frejlev in west to Svenstrup in south and the eastern part of Aalborg. Jørgen Kannik has been part of Danske Fragtmænd for 30 years and operates 22 trucks. These are primarily 12 and 18 ton trucks for urban delivery, a few tractor-semitrailer trucks and three 3,5 ton vans. During the day each of Jørgen Kanniks trucks typically does two roundtrips from the terminal with deliveries and pickups (Kannik 2020)

In the case of events in the tunnel in the north-bound lane, the traffic will typically divert through Aalborg city center and try to cross the Limfjord at the Limfjord Bridge. Jørgen Kannik explained:

> *"Respondent: If the congestion start and we can't move, then the side roads and the ramp-roads becomes congested too. So whether it is the tunnel or the Limfjord Brigde does not matter, it is the same.*
>
> *Interviewer: Which areas in Aalborg are typically affected by congestion - can you try to elaborate on that?*
>
> *Respondent: For some reason the city center is affected, because you have to drive via Vesterbro.*
>
> *Interviewer: Okay, so when saying the city center, how long does that include?*
>
> *Respondent: Well, actually all the way out to Øgade neighbourhood, if you start in the Håndværker neighbourhood and drive that way to get past Østre Anlæg and that direction.*
>
> *Interviewer: How far out does it usually go?*
>
> *Respondent: I think it is very different.*
>
> *Interviewer: Is it all the way out to the Mill?*
>
> *Respondent: Yes, technically it can be. That is where people start to exit the highway if the highway is blocked, then you try to drive via Vesterbro, then it starts there." (Kannik, 2020)*
>
> *"Repsondet: Hvis det sander til, og vi ikke kan komme frem, så sander sidevejene og tilførselsvejene til. Så om det er tunnellen eller Limfjordsbroen, der er sandet til, det er det samme.*
>
> *Interviewer: Hvad for nogle områder i Aalborg bliver typisk ramt, kan du opridse det?*
>
> *Respondent: Det gør midtbyen faktisk af en eller anden grund, for man skal over Vesterbro.*
>
> *Interviewer: Okay, så når du siger midtbyen, hvor er det så ud til?*
>
> *Respondent: Jamen, det er faktisk helt ude fra Øgadekvarteret, hvis du starter nede ved håndværkerkvarter, og så den vej op for at komme over Østre Anlæg og den vej.*

Interviwer: Hvor langt pelejer det at gå ud af?

Respondent: Det er jo meget forskelligt synes jeg.

Interviwer: Er det helt ud til møllen også?

Respondent: Ja, det kan det rent teknisk godt. Der starter folk med at køre af. Hvis nu motorvejen er spærret, så prøver man bare at køre ind over Vesterbro, så starter det der." (Kannik 2020)

The consequence is that Jørgen Kanniks trucks are delayed:

"Respondent: It leads to longer waiting time, because people want to try all the shortcuts and they go through the city center, and like you say, try to cross the bridge, because that is the only other way across the fjord, right. Then it leads to queue all the way up and down Vesterbro - which is totally hopeless - but also the ways leading to Vesterbro.

Interviewer: But how does it affect your shipments?

Respondent: Well, of course we are reach the destination slower." (Kannik, 2020)

"Respondent: Det giver jo noget længere ventetid, for alle folk de vil jo prøve smutvejene og smutvejene, det er så bare gennem byen og som du siger, at komme over broen - det er jo det eneste sted, der er ikke. Så det giver jo altså kø op og ned at Vesterbro eksempelvis - der er det virkelig håbløst - men også vejene optil Vesterbro.

Interviewer: Men hvordan påvirker det jeres leverancer?

Respondent: Ja, der kommer vi selvfølgelig noget langsommere frem." (Kannik 2020)

The following example gives more detail:

"Respondent: It simply takes longer time to reach our destinations, right, and that means that just picking up pallets which normally takes 3 hours might take 3,5 hours on that given day. So if you multiply that with 20 drivers or something like that, then it suddenly adds up. If 20 are stuck in the congestion - we don't always have that - but dependent on how many who are stuck - and it is very individually where they are placed. But it can very well be some hours that day which have to be payed as overtime" (Kannik, 2020)

"Respondent: Det tager længere tid at komme frem simpelthen, ikke, og det gør jo bare, at for at hente de paller ind, som normalt tager tre timer, så tager det måske 3,5 timer den dag. Så ganger du det med 20 chauffører eller sådan noget, og så render det jo op. Hvis det er 20 der hænger i køen, det er ikke altid vi har, men alt efter hvor mange, der nu hænger der og det er jo meget individuelt, hvor de er henne. Men det kan godt blive til nogle timer den dag, som skal betales i overtid." (Kannik 2020)

Asked about whether Jørgen Kannik contacts the customers to tell that they are delayed, he replied that this is rarely done:

> *"Respondent: No it is rarely - well there are a few customers, but most customers know it and most of them have a great understanding for it. If we have to pick up something around 15.00 or 16.00 then we might be at the customer a bit later and most customers have an understanding for that. And they can also see the queue when they leave work after we have left." (Kannik, 2020)*

> *"Respondent: Nej, det er sjældent - altså der er nogle enkelte kunder, men de fleste kunder ved det jo også og langt de fleste har også stor forståelse for det. Altså hvis vi skal hente noget et sted kl. 15-16 eller sådan noget, så kan det godt være vi kommer senere ud til kunden og det har de fleste kunder også forståelse for det. Og de kan så også se, når de selv skal til at hjem efter at vi er kørt, så er køen der jo stadig væk." (Kannik 2020)*

The timing of the events in the tunnel is also important. If the events happen around midday the consequences are not as significant in the adjacent road network as if it happens in the afternoon peak-hour traffic:

> *"Respondent: …If anything happens around 11.00 in the morning then it is rarely noticeable, because it is cleared pretty quickly and the pressure is not as bad at that time. It comes around 16.00, the rush hour. At that time it goes completely nuts." (Kannik, 2020)*

> *"Respondent: ...hvis der sker noget der kl. 11 om formiddagen, så er det sjældent at man lægger mærke til at der har været noget galt, det får man ryddet rimelig hurtigt, og der er ikke det samme pres der. Det kommer først ved myldretiden kl. 16. Det går helt galt." (Kannik 2020)*

Another consequence of the delays is that the trucks arrive later back at the terminal in the evening, and therefore work in the terminal to sort the freight for outgoing line-haul trucks during the late evening becomes delayed also, which in turn influences the operation cost in the terminal.

The impact of delays to the terminal is important, because these can cause a ripple effect through all of Danske Fragtmænds terminal operations. The terminal operation runs 24h a day from Sunday evening until Friday evening, and there is no slack in the plans. Therefore, a delay can generate a long range of delays that keys going until the end of the week. The terminal CEO in At the terminal in Aalborg staff at the terminal has to be done sorting the collected freight at 20.00 in the evening. At 21.00 in the evening the last line-haul trucks have to leave the terminal. If the collected freight, i.e. Jørgen Kannik trucks or trucks from the other companies delivering from the terminal is delayed, then the sorting process is also delayed. As an example, if the incoming trucks are delayed two hours then the terminal staff is done sorting at 22.00 instead of 20.00. This means that the last line-haul trucks leave at 23.00 instead of 21.00. If we take the truck that drive to the terminal in Odense, then this truck will arrive in Odense two hours late, and after turnaround in Odense it will depart two hours late to Aalborg again. Now the terminal in Odense is also delayed as this terminal was waiting

for line-haul from Aalborg. The next morning the line-haul from Odense arrives two hours late in Aalborg, whish delays the sorting in Aalborg, which means that the delivery trucks depart late on their first trips and are late during the day. And so the delays can continue. Sometime a delay therefore continues to "live" in the terminal operation throughout the week until Friday evening when the operation is shut down. Sunday the operation begins on time again. When asked about the impact of delays in January of 2021, the terminal CEO gave the example that one single traffic accident on a highway in Zealand the previous week had caused a day which had generated delays which had spread to all the terminals in Danske Fragtmænd. Likewise, it has a significant impact on the operation if the Great Belt Bridge is closed as this hits a number of line-haul trucks.

This impact on the terminal operation shows that there is a significant cost associated delays as staff at multiple terminals will experience waiting time and work extra hours as a result.

Regarding the timing it is also worth noting that before public holidays and times with increased shopping, ex. Black Friday, pressure on the adjacent road network is increased, which increases the problems faced for freight delivery on these roads if there are events in the Limfjord Tunnel.

> *"Interviewer: Are there certain times for you which are critical in relation to the infrastructure, where you think 'today there must not be a traffic accident'."*
>
> *Respondent: That is typically before the public holidays. Both because people are busy shopping for Easter and such things. And then because there are more cars on the roads - some might take time off in connection with a holiday, so there is more traffic there too.*
>
> *Interviewer: So that includes Black Friday, Easter, and all of those things…*
>
> *Respondent: It can get exciting there, yes, or it is exciting. Also because a road like Nyhavnsgade are congested in advance. If they have to reach Nytorv. And if you look at the road leading to City Syd - okay that is not related to the tunnel - but there are so many more cars on the roads. And we can feel that." (Kannik, 2020)*
>
> *"Interviewer: Er der nogle bestemte tidspunkter i forhold til jer, der er kritiske for infrastrukturen, hvor du tænker, det må bare ikke være i dag, hvor der er uheld.*
>
> *Respondent: Det er typisk op til helligdage. Både fordi at folk har travlt fordi de skal handle ind til påske og sådan nogle ting. Også fordi der er ekstra mange biler på vejene - nogle tager måske fri op til en helligdag, så er der mere trafik der også.*
>
> *Interviewer: Så det vil sige, Black Friday, påske og alle de der ting…*
>
> *Respondent: Det kan godt blive spændende ja eller det er spændende. Også fordi sådan som Nyhavnsgade, den sander jo til i forvejen ikke. Hvis de skal ind til Nytorv. Og tager man så vejen ud til City Syd - okay det er så ikke lige noget med tunnellen at gøre - men der er simpelthen bare flere biler på vejene. Det kan vi godt mærke." (Kannik 2020)*

The deliveries from terminals and pickup to from terminals is the largest operation within Danske Fragtmænd. The second most important is the direct deliveries done by Danske Fragtmænd Transport A/S which full load or less-than-truckload. When an order exceeds a certain size threshold either in relation volume or weight the handling costs in the terminals mean that it is preferable to do a direct delivery where a truck pick up the order at the sender and deliver to the receiver.

Danske Fragtmænd Transport A/S operates approximately 150 trucks, of which Danske Fragtmænd Transport A/S owns 25 and subcontracts the rest. The trucks are all tractor semitrailer setups. A few trailers are city-trailers which can turn on the last axel, and for deliveries where it is necessary to use a front-trailer the delivery is subcontracted to Danske Fragtmænd A/S. Let us now turn to how events impact this business area.

To understand the impact of delays in this business area it is important to understand that a general tendency is an increasing demand for precise delivery timewise:

> *"Respondent: …But what we experience is, that slot deliveries are becoming popular and the slots are becoming tighter and tighter. The customers or the consignor want the goods to stay as long time as possible on the sender site. So you can deduce that our lead time for delivery is becoming smaller and smaller.*
>
> *Interviewer: Yes*
>
> *Respondent: And that is typically because that the lead time for the consignor to reciver is minimized. And they typically reduce the time you have for thee transport.*
>
> *Interviewer: That that means, that you have tighter and tighter deadlines to operate with?*
>
> *Respondent: Yes, and that affects the dispatching, so we need more trucks than what might elsewise have been necessary. So, just that can actually increase the number of trucks on the roads. That we have limitation in relation to when we deliver." (Jespersen 2020)*
>
> *"Respondent:... Men det vi oplever er, at det bliver mere og mere slotleveringer og det bliver mere og mere tidsbegrænsninger på de disponeringer. Kunderne eller afsenderen vil have godset så lang tid som muligt på afsenderstedet. Og så kan man sige, at vores lead time til levering bliver mindre og mindre.*
>
> *Interviewer: Ja.*
>
> *Respondent: Og det er jo så også fordi, at leadtime for afsenderen til modtager bliver mindre og mindre. Så trækker de typisk, der hvor du har transporten.*
>
> *Interviewer: Så det vil sige, at I får hårdere og hårdere deadlines at køre efter?*

Respondent: Ja, og det betyder jo i disponeringen, at vi bliver nødt til at have flere biler ind, end der måske har været nødvendigt. Så det i sig selv kan godt øge antallet af biler på vejene faktisk. At vi har begrænsninger i hvornår vi leverer." (Jespersen 2020)

Turning to the impact of unforeseeable delays, the consequence for Danske Fragtmænd Transport A/S is different in comparison to the operation we have seen in the previous cases, because a large part of the drivers sleeps in their trucks. They leave home Sunday or Monday morning, and then they are on a trip until Friday evening. This means that typically, during the afternoon peak hour traffic, where the impacts of unforeseeable events are most significant, the drivers are sleeping:

"Respondent: … we are actually lucky that most of our deliveries today are outside those hours, so during the afternoon rush hours most of my drivers are asleep because we deliver at night and during the early mornings. So therefore, in the afternoon probably half of my drivers are sleeping. So of course, that helps our setup a bit, it can be different for others if you drive in the daytime. We of course plan that it might take a bit longer in the morning, but those accident where it shuts down completely, we can't take… well yes… the first driver obviously calls back and tells about the queue and people start to find other ways. I think I have said it before, traffic is like water, it flows where it is easiest." (Jespersen, 2020)

"Respondent:... vi er faktisk så heldige, at meget af det vi leverer i dag, det er udenfor de her tider, så når du har eftermiddagstrafikken, der lægger de fleste af mine chaufførerne egentligt og sover, fordi de leverer meget om natten og meget tidligt på morgenstunden. Så om eftermiddagen, der har jeg nok halvdelen af chaufførerne, der sover. Så det hjælper selvfølgelig lidt på vores setup, det kan jo være anderledes for andre, hvis man kører mere i dagtimerne. Vi planlægger selvfølgelig efter at det tager lidt længere tid om morgenen men de der uheld, hvor det lukker helt ned, det kan vi jo ikke… jo… den første mand ringer selvfølgelig tilbage og siger, at nu er der kø og folk begynder at finde andre strømme - jeg tror, at jeg har sagt det før - trafik er jo ligesom vand, så der flyder vand hvor det er nemmest." (Jespersen 2020)

The chief dispatcher explained the daily work-rhythm:

"Respondent: We drive all around the clock. The main part of our trucks - about half - starts between 23.00 and 02.00 at night, and then they drive until there is no more to do or until their disposal time is up. That means, that half of the drivers rest or finish their workday around noon. But we have trucks driving 24/7, because there are also people showing up in the morning and then driving until the evening.

Interviewer: Does all the drivers start from the terminal and end home again - or is it a trip spanning several days?

Respondent: In most of our trucks the drivers sleep in the truck where he ends. I guess 75% of the trucks we have at our disposal that do this.

Interviewer: So that mean they take off Monday morning and return here on Friday?

Respondent: Yes, or Sunday evening. Some of the trucks drive for 6 days one week and 5 days the next week. We also have the haulers which all employ the trucks 6 days a week. But there typically, you drive for 3 days and have 3 days off." (Køpke, 2020)

"Respondent: Vi kører hele døgnet. Hovedparten af vores biler - cirka det halve af flåden - starter mellem kl. 23 og 02 om natten og så kører de jo så indtil der ikke er mere at lave, eller indtil deres rådighedstid er brugt op. Det vil sige, at halvdelen af bilerne går på hvil, eller afslutter deres arbejdsdag omkring middagstid. Men vi har biler der kører 24/7, fordi der er også biler der møder ind om morgenen og så kører til om aftenen.

Interviewer: Kører de alle sammen ud fra terminalen og ender hjemme igen, eller er det på tur i løbet af ugen?

Respondent: I de fleste af vores biler, der overnatter chaufførerne i lastbilen, hvor langt han nu når. Jeg vil skyde på, at det er 75% af de biler, som vi råder over som gør det.

Interviewer: så det vil sige, at de kører afsted mandag morgen, og så er de hjemme igen fredag.

Respondent: Ja, eller søndag aften. Nogle af bilerne kører 6 dage den ene uge og 5 dage den anden uge. Vi har også vognmændene, der allesammen beskæftiger bilerne 6 dage om ugen, men der er det så typisk at man kører 3 dage og har 3 dage fri." (Køpke 2020)

The dispatchers in Danske Fragtmænd Transport typically monitors the transport and optimizes continually. One perspective on the work of the dispatchers is that they are problem solvers for the customers and their job is to make sure that the freight is moved so that it arrives when it is needed by the receiver.

To understand this, we need to clarify the difference between the trips done by drivers in Jørgen Kannik A/S and the trips done by drivers in Danske Fragtmænd Transport A/S. When the drivers in Jørgen Kannik A/S meet in they start their work by a gate in the terminal in Aalborg. At this gate a pile of freight awaits the driver. This freight has arrived at the terminal the day before in case it is sent locally or by line-haul during the night from other terminals. During the early morning hour staff at the terminal sort the freight according to what areas it is destined for and each gate receives the freight destined for a given area. When the driver arrives at the gate he/she goes through the freight and decides what route to drive and what order to do the delivery in in order to deliver the freight most efficient. Thereafter he/she loads the truck so that the freight is sorted according to this delivery plan. Therefore, in case of events blocking the route planed it is up to the driver to manage how to respond to the new situation. In Danske Fragtmænd Transport A/S a department of dispatchers are planning the routes, and these dispatchers are in constant contact with the drivers and monitors the progress of the trucks. Therefore, in the world of the dispatcher, events on critical road infrastructure are just one type of many types challenges they face during a day. The challenges may be a customer who need to have an order delivered faster than planned, it may be a shipment that is delayed for pickup, and it might also be an accident blocking a highway. As the dispatchers

spend their entire day as problem solvers planning routes and adapting plans to meet unforeseen circumstances, unforeseeable events is just one of many challenges the dispatchers are facing.

The only buffer the dispatchers can use is to load the trucks and deliver early if that is possible, as that frees capacity and minimized the risk of being late:

> *"Respondent: …Well, the only buffer is those cases where there is a possibility of loading early and deliver early, then we do it. That is the only buffer we have." (Køpke, 2020)*

> *"Respondent: ... altså den eneste buffer det er jo, at der hvor vi har mulighed for at læsse i god tid og levere det i god tid, der gør vi det jo. Det er den eneste buffer der er." (Køpke 2020)*

When planning the rotes, and dealing with new situations, the dispatchers uses a use a prioritizing order, ranging the freight in what is most important that is delivered at time:

> *"[The priority list] is dependent on which freight our big customers think is the most important to have delivered on time. That is fresh food which has an expiry date - and then it is food and non-food at last. And then the cardboard for the production companies, where the production is running regardless of us showing up or not - that is typically slaughterhouses or dairies." (Køpke, 2020)*

> *"[prioriterings rækkefølgen] er jo hvad gods en af vores store kunder mener er mest vigtig bliver leveret til tiden. Og det er jo ferske varer - så det har en udløbsdato, og så det er food og nonfood til sidst. Og så er det pap til de der produktionsvirksomheder, hvor produktionen kører uanset om vi kommer eller ej - det er typisk slagterier eller mejerier." (Køpke 2020)*

The impact of unforeseeable delays depends as we have seen previously on the type of good transported, as the division CEO explained:

> *"… We have some shipments of bottled water from Brande to a warehouse in Horsens, which always has 1.000 pallets of water in stock at a parcel storage. We just have to pick up what is produced and drive it to the warehouse. It really doesn't matter is we are 1-2 hours delayed. Likewise, if we drive grain home from Zealand. It is just a 10.000 tons pile of grain which we have to relocate within a month. There it doesn't matter at the destination point either- it just has to be placed in another silo – so nothing gets passed on from that point. If we look at our cardboard packaging, it is made so that the pallets of cardboard produced at the factory is used directly in the production at the recipient. So, if we are late with the packaging for the chicken slaughterhouse in Vinderup and they are out of cardboard boxes, then their production comes to a halt, they cannot slaughter the chickens because they don't have anything to put them into. Then suddenly it is a completely different cost we are talking about, because an entire factory is not in operation. There is an slaughter-line which is stopped. This is to two extremities. It could also be another production company which produces something where our delivery is very needed." (Jespersen, 2020)*

"… vi har nogen overførsler af flaskevand fra Brande ind til et lager i Horsens og der står altid over 1000 paller vand inde på det stykgodslager og vi skal bare tage det der bliver produceret og så køre derind. Der er det jo ligegyldigt om vi holder 1-2 timer ekstra. Ligeledes hvis vi kører korn hjem fra Sjælland. Jamen der ligger en bunke korn derovre på 10.000 tons, som vi skal have flyttet over en måned. Der er det jo også ligegyldigt i den anden ende - det skal jo bare ligge i en anden silo - så der er ikke noget der kommer videre derfra. Hvis vi så tager vores papemballage… der er det jo lavet sådan, at de paller med pap, der bliver lavet på fabrikken, de er egentligt, skal gå direkte ind i produktionen ved modtageren. Hvis vi så kommer for sent med papemballage til kyllingeslagteriet i Vinderup og de ikke har flere af papkasserne, så går deres produktion i stå - så kan de jo ikke slagte flere kyllinger, for de har ikke noget at putte dem i. Så er det jo lige pludseligt en helt, helt anden omkostning vi snakker, for så står en hel fabrik stille. Der står en slagterlinje, der holder stille. Det er sådan de to yderpunkter i forhold til tingene. Det kunne også være en anden produktionsvirksomhed, som laver noget hvor det er meget nødvendigt." (Jespersen 2020)

This is the same point as we saw in the Vendelbo Spedition case, i.e. the difference between business to business deliveries for the oil industry and business to consumer deliveries in the kitchen and furniture industry.

When planning the routes, the dispatchers take the daily peak-hour congestion into consideration and plans around this. And when possible delivers early.

"…Well, we know many of the places with congestion and typically we ask the drivers to start earlier or later so they avoid the rush hours. We ask them to drive to the recipient and stay there for the night, so they can make the delivery in the morning and then we are sure it is there on time, if it is possible. We also have night deliveries which has to be delivered before 06.00 and some customers where we can load at 18.00. So in those cases we typically do that and delivery it directly afterwards, because then we are sure to be there in time." (Køpke, 2020)

"… Altså vi ved jo godt at mange af stederne, hvor der er trængsel, og typisk beder vi jo bilerne om at starte tidligere eller senere, sådan at de undgår myldretrafikken. Vi beder dem om at køre frem til modtageren og overnatte der, sådan at de kan levere om morgenen, så vi er sikre på at det kan leveres til tiden - hvis det kan lade sig gøre. Vi har også mange natleveringer, der skal leveres inden kl. 06 om morgenen og der har vi nogle kunder, hvor man kan slutlæsse kl. 18 om aftenen og det gør vi typisk og så kører vi direkte ud og leverer det, for så er vi sikre på, at det er leveret til tiden." (Køpke 2020)

It is interesting to note the solution of getting the truck into position to deliver the day before, to make sure that the truck is capable of delivering at the correct time the day after. This relates to the approach used by AVAS of creating places to park trucks and in Aarhus, Vejle, Odense and Køge so that the truck can start and be at the delivery point in time without having to go past roads where the risks of delays are high, such as the E45 in east Jutland or the E20 across Funen and Køeg Bugt.

Looking at the costs associated with the delays, some are direct and some are indirect and very difficult to measure:

"Respondent: One of our big customers send us a Gatehouse [inventory statement], where they measure delays and we have to account for the delays down to every single minute. So that is a huge focal point for us.

Interviewer: Okay, what are the costs if you screw up and end up being 10 minutes late?

Respondent: If it is repeated multiple times, then it will be something which will be the agenda at a meeting. It can be special areas, and it is typically the areas farthest out on the route where you will have delays.

Interviewer: Can you give any examples? It is always good when making a report.

Respondent: Well, we load in Højberg and it would be a place like Nykøbing Falster or Helsingør, Dragør. Those destinations which are farthest from Højberg.

Interviewer: Now I want to talk about the costs. So if you are called in for a meeting because the delays have happened repeatedly, then it is actually a cost for your brand value towards the clients.

Respondent: Yes, sure it is a cost.

Interviewer: What about the compensation claim, is that also something you experience?

Respondent: We haven't experienced doing our business so badly that we have been met with a compensation claim yet. But it is in our contract, that when delays occur, they can send a compensation claim. But it hasn't been realised yet." (Køpke, 2020)

"Respondent: En af vores rigtig store kunder, der hver dag, der kommer der en Gatehouse [opgørelse], hvor de måler forsinkelser, og der skal vi svare på forsinkelser helt ned til hvert enkelt minut, så det er et område, som vi har stort fokus på.

Interviewer: Okay, hvad er omkostningerne hvis I klokker i et og kommer 10 minutter for sent?

Respondent: Altså hvis det er gentagende, så er det noget, der bliver taget op på et møde. Det kan være specielle områder, og det er typisk de områder, der ligger længst væk på turen, hvor man vil have forsinkelser.

Interviewer: Kan du give mig nogle eksempler? Det er altid godt, når man skal lave en rapport.

Respondent: Jamen altså, vi læsser jo i Højberg og det vil jo være sådan noget som Nykøbing Falster og det kan være Helsingør, Dragør. De destinationer, der ligger længst væk fra Højberg.

Interviewer: Nu kommer det så lidt over i omkostninger, så hvis I nu blev kaldt til møde fordi der er gentagende forsinkelser, så er det jo egentligt en omkostning for jer i jeres brandværdi overfor kunderne.

Respondent: Ja, det er da en omkostning.

Interviewer: Hvad med erstatningskrav; er det også noget I kommer ud for?

Respondent: Vi har ikke oplevet endnu at træde så meget ved siden af så vi har fået erstatnings-krav, men der står faktisk i vores kontrakt, at ved forsinkelser, så kan de godt sende erstatnings-krav. Men det er ikke blevet realiseret endnu." (Køpke 2020)

Elaborating on the consequences of delays caused by unforeseeable events he elaborated:

"Respondent: Well, we contact the customer and say 'listen friends, we won't be there at the arranged time because we are stuck in a traffic accident' and it is force majeure, because you cannot help it. So typically, the customer chooses to wait for us to arrive or asks to have the delivery the following day at a newly arranges time.

Interviewer: Ok, can you give any examples from practice? From recently if there have been any accidents, where you have done it.
Respondent: Yes, we have some warehouses which have their deliveries no later than 22.00 and in those cases we contact the sender and tell them we will be there at 23.00 instead. And then they can choose to wait for us or have the delivery at 05.00 the next morning. And it is the customers who decides. We have for example tried driving packaging to slaughterhouses where it the slaughterhouse runs whether or not we come anyway. And in those cases they typically wait for us. And also they have staff at work anyway.

Interviewer: How are your costs in such situation? What extra cost does it apply to you and DF?

Respondent: Well, in our own trucks the driver is paid by the hour and this is a cost. And we have some external suppliers who are paid by the hour. It is a cost too. Then we have some drivers paid by number of driven kilometers, the number of kilometers they drive, so that is not an extra cost to us. Because we aren't responsible for it and neither is the hauler, so we can't pass on the bill. So of course it affects us." (Køpke, 2020)

"Respondent: Jamen altså vi kontakter jo kunderne og siger "prøv at høre her venner, vi kommer ikke til aftalt tid på grund af, at vi er ramt ind i det her trafikuheld" og det er jo force majeure, det er ikke noget man kan gøre for. Så typisk vægter kunden jo at vente på at vi kommer eller beder om at få leveret næste dag og aftalt tidspunkt.

Interviewer: Okay, kan du give nogle eksempler fra praksis? Tilbage i den seneste tid, hvis der har været nogle uheld, hvor I har fået gjort det.

Respondent: Ja, vi har nogle varehuse, der får varer senest kl. 22 om aftenen og der kontakter vi afsender og siger, vi kommer først i det varehus kl. 23 i stedet for. Så får de valget om de vil vente på os eller om de vil have det næste dags morgen kl. 05. Og det er jo kunden der afgør det. Vi har også for eksempel prøvet at køre emballage til slagterier, hvor det er det samme, hvor slagteriet kører uanset om vi kommer eller ej. Og der venter de typisk også på os. Og der er der jo også naturlig bemanding.

Interviewer: Hvordan så i forhold til jeres omkostninger i sådanne situationer? Hvad løber der på af ekstra omkostninger for dig og for DF?

Respondent: Jamen, egne biler, der er chaufføren selvfølgelig aflønnet på timeløn, og det koster, og vi har også nogle eksterne leverandører, der også er afregnet på timeløn. Der koster der også penge. Så har vi nogen der er afregnet på kilometer, altså hvor mange kilometer de kører - og der koster det os ikke. For vi kan jo ikke gøre for det og det kan vognmanden jo heller ikke, så vi kan jo ikke sende den regning videre. Så selvfølgelig påvirker det os." (Køpke 2020)

This quote highlights a new issue which further complicates the calculation of direct cost for the logistics companies. As mentioned before, Danske Fragtmænd Transport A/S subcontracts around 125 trucks, and as the quote shows these are settled in two ways, either per time they drive or per distance they drive. If the subcontracted truck which is delayed due to an event is payed per time it drives, then the delay will cause a direct extra cost for Danske Fragtmænd Transport A/S. On the other hand, if the subcontracted truck is payed per distance driven, then the delay will not change the cost for Danske Fragtmænd Transport A/S. This means that delays may cost direct and indirect costs (brand value), or only indirect costs. The direct cost in the latter example is incurred by the subcontracting transport company.

We saw earlier in the Vendelbo Spedition case that one issue was drivers running out of driving time. This issue is not significant in Danske Fragtmænd Transport A/S:

"Interviewer: What is the situation if you run out of driving time? Is that something you have problems with or a challenge or do the drivers just sleep in the trucks when they run out of time?

Respondent: Yes, typically they sleep at a decent parking place, where they can have a shower and get something to eat. We use the freight centrals as much as possible, because there the goods can be locked up.

Interviewer: Okay

Respondent: And there is a canteen area and nice shower conditions. So, our trucks or drivers and the haulers have a brick to enter and have a shower.

Interviewer: Okay, so it is not a huge problem to run out of driving time in these situations?

Respondent: No it isn't. And the transport coordinators take the driving-resting-time into account when calculating how far they have to drive and when they have to start again. Because of course we obey by the rules." (Køpke, 2020)

"Interviewer: Hvordan i forhold til hvis I løber tør for køretid? Er det noget I har problemer med eller er det også en udfordring eller overnatter de bare i bilen, når de løber tør eller hvordan?

Respondent: Ja, typisk så overnatter de hvor der er en okay parkeringsplads, hvor man kan holde ind og få et bad og noget at spise. Vi bruger fragtcentralerne alt det vi kan, for der er godset jo bag lås og slå.

Interviewer: Okay

Respondent: Og der er jo kantineforhold og badeforhold. Så vores biler eller chauffører og vognmænd, de har sådan en brik, så de kan komme ind og få et bad.

Interviewer: Okay, så det er ikke et stort problem med at løbe tør for køretid i de situationer her?

Respondent: Nej det er det ikke. Og disponenterne tager selvfølgelig højde for kørehviletid og hvor meget rådighedstid man har, hvor langt man kan køre, og hvornår man kan starte igen. For vi overholder jo selvfølgelig reglerne." (Køpke 2020)

As can be seen from the quote the problem with drivers running out of driving time is not an issue in Danske Fragtmænd Transport A/S as the drivers typically are on trips lasting several days, and therefore just sleeps in the trucks when they run out of driving time. There is, therefore, no need to use resources to get the stranded drivers and trucks back to the terminals. It is, in the quote, also interesting to note that Danske Fragtmænd Transport A/S tries to arrange the trips so that rest is done at terminals so that the freight is safer compared to public rest areas.

Looking at other parts of the operation of Danske Fragtmænd, then there is also the line-haul between terminals done at night. These trucks are rarely exposed to events due to the timing of the driving, but on the other hand, if they are delayed, for example if the Storebælt Bridge is closed, then the consequences are significant as this delays the terminal sorting and the morning departures from the terminals:

"You can also take our bulk-division as an example - they bulk parcel goods between the terminals. They also drive while the rest of us watch the news and sleep, and it is almost the same - if there is a delay on one of those transports, and there are 20 trucks waiting for goods the next morning. If 20 trucks have to wait for 1 hour then it adds up. So it is almost just like an intercity bus it just has to drive." (Køpke, 2020)

"Du kan også tage vores bulk-afdeling, der bulker stykgods mellem fragtcentralerne. De kører også mens vi andre ser nyheder og sover, og det er jo lidt det samme; er der en forsinkelse på sådan en transport, og der holder 20 fragtbiler dagen efter, som venter på godset - skal de 20

biler vente en time, så løber det op. Så det er bare sådan nogle rutebiler, der bare skal køre." (Køpke 2020)

Looking at the overall cost associated with the transports the CIO of Danske Fragtmænd explained:

"What we looking at here is two costs. It is the cost for our customer, but then there is also another larger cost, and that is the cost for our customers customer. And the last one is probably the most important one; it is also one of the things we have noticed in the Corona-crisis - all companies today are extremely lean in their supply chain. That means that every variation; the Storebælt Bridge closing down, the Limfjord Tunnel closing down, the Vejlefjord Bridge experience congestion - all have enormous consequences downstream. Whereas, traditionally we have seen our clients as upstream and the cost shows there. And it also does, but that it just delayed, whereas the downstream cost is instantaneous - showing today." (Preisler 2020)

"Det som vi sidder og kigger på, det er; der er to omkostninger her. Der er omkostningen for vores kunde, men så er der den større, der er omkostningen for vores kundes kunde. Og den sidste, det er nok den vigtigste; det er en af de ting vi også har set i Coronakrisen, det er jo at alle virksomheder i dag jo er ekstremt lean i deres supply chain. Det vil sige, at enhver variation - Storebæltsbroen der lukker, Limfjordstunnellen der lukker, Vejlefjordbroen der sander til - har enorme konsekvenser downstream. Hvorimod vi traditionelt har kigget på vores kunder som værende upstream og så omkostning kommer der. Det gør den også, men den er bare forsinket, hvorimod downstreamomkostningen er her og nu - altså i dag" (Preisler 2020)

The important thing to note here is the impact downstream where a significant consequence is. This can be compared to the situation within Arla Foods, where one issue was the costs of delays in the logistics operation. Another was the costs if the delays exceeded a threshold where the safety stock was depleted, and the production came to a standstill.

Having now presented the five company cases it is time to summarize the findings in the analysis in the next chapter.

5 Analysis

It is now time to synthesize the findings from the five cases presented in the previous chapter. Let us begin by focusing on the two types of delays seen in the cases.

5.1 Foreseeable daily congestion delays versus unforeseeable events

The cases showed that daily peak hour congestion delays are handled by dispatchers and drivers by adding extra time to the planned trips. When possible, trips are planned outside of peak-hour traffic and if this is not possible extra time is added to account for the delays caused by peak hour traffic. Due to experience, dispatchers and drivers apparently have a relatively good knowledge about what daily delays to expect and how much time to add.

Looking at the delays caused by events such as accidents, i.e. events that are impossible to foresee, the situation changes. The case companies do not add extra time in plans to handle these events, and therefore when they occur, they have an impact on the operation. The next subsections will explore these impacts in detail, but before turning to these we should look at the way in which cost of unreliability is handled today in Denmark.

In Denmark, the cost of delays is assumed to be 1,4 times of the cost of ordinary travel time, according to (The Danish Road Directorate 2020), as mentioned in section 3. In Sweden 100% is added, but as argued by (Andersson, Berglund et al. 2017), there appears to be no scientific foundation or explicit reasoning behind this Swedish number. Looking at the case studies and the way in which daily foreseeable congestion are handled in logistic companies, this approach of adding a percentage to the cost makes sense, because this percentage can be interpreted as a measure of how well the drivers and dispatchers are capable of guessing the average daily foreseeable congestions delay.

When looking at the practice of adding extra time to the routes building on experience in the case companies, we can say, that if the drivers and dispatchers are capable of guessing the delay precisely then the percentage added should be 0%. 40% can be interpreted as saying that on average the drivers and dispatchers add 40% more time more than needed to the route when looking at the actual delays that occurs. Likewise, adding 100% can be interpreted as saying that the drivers and dispatchers add double the time actually need. From another perspective on the same issue, we can say that when putting a cost on the daily delay, the cost does not relate to the actual delay that occurs on the road. The costs relate to the time the driver or dispatcher think they will be delayed when planning their trips. For example, if a dispatcher has to plan a trip during rush hour on a given road, and he/she adds 20 minutes to this trip to accommodate for the delays caused by the foreseeable congestion, then the cost to the company equals 20 minutes of driver time no matter if the actual congestion on the given day only caused a 15 min delay. The remaining 5 minutes is still lost as waiting time before delivery in the plan.

Therefore, the approach of adding a percentage to the cost of ordinary travel time makes sense, but further studies are needed to estimate whether 40% is the right measure.

Let us now turn to the costs of the unforeseen events.

5.2 Effects in the logistics operations caused by the risk of delays

(Andersson, Berglund et al. 2017) distinguishes, as discussed earlier, between direct and indirect effects. The direct effects being the ones caused by delays, the indirect being the effects caused by the risk of delays. The case studies clearly shows that logistics companies invest to minimize the risk of delays by events. We saw that AVAS has bought and maintains sites in the larger cities to minimize the distance the trucks have to drive to get to the receiver, and thus minimize the risk of the truck getting delayed in unforeseen events before arriving at the receiver. We saw that Danske Fragtmænd Transport A/S tries to drive early, and if possible the day before, so that the driver can sleep in the car near to the receiver. We saw that Schulstad has prepared their vehicles for night-time delivery to minimize the need to drive in peak hour morning traffic where the risks of events are high. We saw how Arla has extra trailers located strategically to be used in case of events such as snowstorms.

One impact of the risk of events is thus investments made by the logistics companies to their operation to avoid driving in peak hour traffic where the impact of events is highest. As we saw in the Danske Fragtmænd case, the impact of events outside of peak hour traffic is less severe.

For further research in this direction the next step should be to analyse the costs used by the logistics companies on these effects, i.e. how much does logistic companies use on extra terminals/sites to avoid driving on roads with high risks of events, how much do they use on backup vehicles/capacity etc. An analysis of this will be crucial to understand the costs of delays for freight transport.

It should also be mentioned in relation to this issue that the Limfjord Tunnel is potentially influencing the choice of company location. The CEO of Vendelbo Spedition said that the unreliability in the Limfjord Tunnel was an issue in relation to running a company located north of the Limfjord. The Arla case also showed that the Arla Foods' Site Director at the Akafa factory said that due to the Limfjord Tunnel, it would be problematic to have the Akafa factory located north of the fjord. The case of Schulstad also showed the issues in a location north of the tunnel in Pandrup. On consequence of the delays could therefore likely be that existing companies choose to relocate to locations south of the Limfjord and new companies choose strategically to locate south of the Limfjord when choosing their location. Further studies into this dynamic are however needed to quantify this.

5.3 Effects in the logistics operations caused by events

The analysis shows three significant new findings regarding the effects of events upon logistics operations. First, delays can spread geographically to other freight and trucks downstream in the logistics operation. Second, delays can grow in time extent downstream in the logistics operation. Third, trucks on adjacent roads to the critical infrastructure is also delayed. Let us focus on these three issues.

5.3.1 Delays can spread geographically downstream in the logistics operations to trucks and freight which was not near the event

In the Vendelbo Spedition, Danske Fragtmænd and Schulstad cases we saw examples of the consequences of delays to the terminals. First, when trucks are delayed to the terminal this causes waiting time among staff at the terminal which equals extra cost. Second, the sorting of the incoming freight is delayed and the consequences of this is that the sorting finishes later than planned. This means that the staff must work later than planned, which may generate the need for overtime payment. Third, when the sorting is delayed so is the loading of departing trucks and thus the departures. This means that the outbound drivers have to wait until the trucks are ready for departure, which can generate extra cost and the trucks are thus already delayed when their trips from the terminal begin.

When a truck arrives late to the terminal this means that it is not only this one truck that arrives late that will depart late. As the sorting is delayed the delay typically expands in scope to include several departing trucks. In the Danske Fragtmænd case we saw, for example, that one single traffic accident on a highway in Zealand generated delays which spread to all the terminals in Danske Fragtmænd across the country. We also saw in the case of Danske Fragtmænd, that the delays can survive in the terminal operations for days as these are 24 hours a day tightly planned operations during weekdays. Likewise, in the Schulstad case, we saw how a delay of just 15 minutes to the terminal in Pandrup due to delays in the Limfjord Tunnel causes a 15 minutes delay for the delivery of bread the following day.

This research has thus shown that a delay may spread geographically downstream in the logistics operation to include freight and trucks that were not even on the road, when the event happened. This is a highly significant result, which have not been covered in the existing literature on VOT and VOR for freight transport. The implication is that the impact of events is currently underestimated as these are calculated only in relation to the trucks and freight that are delayed on the road by the given event. This research has shown that the delays can spread to more trucks downstream. Further research is therefore highly needed to identify the average growth of events, so that it can be established how underestimated the delays are today.

5.3.2 A delay can increase in time downstream in logistics operations

The cases showed that the length of a delay can grow downstream in the logistics operation. It is in other words not necessarily equal to the amount of time the truck is delayed in the event on the road. The reasons for this being driving time and dependencies in the logistics operations downstream. We saw in the case of Vendelbo Spedition that it often happens that drivers run out of driving time due to events. If this happen, the company has to send another driver to drive the truck home, and in worst case, two extra drivers have to be involved; one to drive the “rescue vehicle” to the stranded driver and back and another driver to drive the truck onwards. The problem of drivers running out of driving time and becoming stranded was also seen in the Schulstad case. In the Danske Fragtmænd case, we saw a less costly consequence, which is that the driver can sleep in the truck and resume the trip the day after. A third example was seen in the ferry departures in the Vendelbo Spedition case: If the sorting at the terminal in Hjørring is delayed above a certain

threshold, then the trucks to Norway cannot reach the ferry in Hirtshals, and thereby the departures have to be postponed to the following day.

This research has thus shown that the length of delays is not necessarily given by the time the truck is delayed on the road due to the event. The length of the delay may grow downstream in the logistics operations. This is a highly significant result, which have not been covered in the existing literature on VOT and VOR for freight transport. The implication is that current analysis of costs of events are underestimated as these calculations rely on the time the event takes on the road. The next step needed in research in this direction is to determine the relationship between the time the event takes on the road and the delay generated downstream in the logistics operations as a consequence of this delay. When this relationship has been established, it will be possible to make more precise estimates of the costs associated with events.

Complicating the picture is also the fact that not all delays are caused by traffic as the AVAS and Schulstad cases also shown. Some are due to traffic events; some are due to customers delaying pickups and some are due to dispatchers or drivers making errors in plans and routs. This also needs to be disentangled in future analysis to understand the impact of traffic compared to the other sources of delay.

5.3.3 Trucks on adjacent roads to the critical infrastructure can also be delayed

The Danske Fragtmænd case showed, that when the Limfjord Tunnel is blocked due to an event, then traffic seeks towards the center of Aalborg and the Limfjord Bridge, but due to the limited capacity of this connection the result is typically widespread congestion and delays in Aalborg city center. The case further showed that this delays the trucks operating in Aalborg south of the fjord, trucks which are not passing the Limfjord tunnel on their trips. This is also a highly significant result, which has not been covered in the existing literature on VOT and VOR for freight transport. The implication is that current analysis of costs of events are underestimated as these calculations only includes the trucks on the road where the event occurs. Future research needs to analyse the extent of this issue in relation to events on critical infrastructure.

The Schulstad case further showed that the planning and restrictions on the road network around the critical infrastructure can push more trucks into rush hour traffic, and thus worsen the costs of freight transport in the event of delays. Schulstad delivers at night in several Danish cities to avoid driving during the morning rush hour, and thus minimizing the risk of being caught in traffic accidents. However, due to Aalborg Municipality not allowing night delivery to the same extent as some other Danish cities, Schulstad has to drive during the morning rush hour in the Limfjord Tunnel to deliver in the morning before the shops open in Aalborg.

Let us now turn to the costs associated with these effects of delays.

5.4 Costs of delays

This research project has qualitatively identified how unforeseeable events on critical infrastructure affect freight transport. However, more research is needed before it becomes possible to quantify the cost of this. The first step should be to quantify the investments made by logistics companies to avoid driving during rush hour. The second step to quantify how delays caused by events grow in time and spread to other trucks and freight geographically downstream in the logistics operation, and how incidents on critical infrastructure affect freight transport on surrounding roads. Once these factors are quantified, we will be able to estimate how much freight one specific event on a given piece of critical infrastructure will in fact delay.

It makes no sense to quantify the costs of delays caused by events at this current stage, because the analysis has shown clearly that we do not know how much freight that is actually impacted by an event. Due to the downstream effects presented above, it is clear that we cannot use the number of trucks or amount of freight waiting in a queue by a given accident as a measure of how many trucks and how much freight that is delayed by this accident. We need to include the trucks and freight delayed downstream in the logistics operations. Once we are able to do this, we can calculate the real number of trucks and amount of freight being delayed in the logistics operations. And when we can do this, we can start to look at the costs associated with these total delays.

There are a number of costs for logistics companies that are relatively easy to determine, e.g. driver costs, equipment costs and terminal costs. Other costs are more difficult to determine, e.g. lost brand value to the customer in case of delayed delivery. The type of goods is also of importance, both for the significance of delays and for costs in the next link in the supply chain. For some types of freight fast delivery is crucial, as we saw in Vendelbo Spedition transports of parts to the oil industry. At the opposite end of the spectrum, there are types of freight where delay does not matter, as we saw in the Danske Fragtmænd case with the transport of water and grain.

The crucial issue here is the importance of timely delivery downstream in the supply chain and this leads the focus to the cost of buffer stocks and production stops. There is a need for further research that can quantify the cost of transport delays within the supply chains of different industries. We saw the costs involved in the Arla case when supply buffers are used up and production stops. From January to August in 2020, the factory stood still for over an hour on three occasions due to delayed trucks carrying packaging. Today, this type of cost is downstream in the value chain by the receiver of the goods and not included in analyses of costs of delay in freight transport. A three-hour delay of a truck with packaging for Arla's factory will therefore today in cost-benefit analyses in Denmark be set at a value corresponding to three hours of delay time for freight transport, which corresponds to DKK 2,394. The cost of between DKK 50,000 and DKK 100,000 that Arla loses due to the fact that the buffer stock is used up during the first two hours and that production is therefore at a standstill for the third hour is not included in the cost-benefit analysis. Again, the conclusion is that the cost of delays due to incidents is underestimated as the consequences for the recipient of delayed delivery of goods are not taken into account. Future research should shed light on how these costs can be included in the analyses.

6.5 Danish infrastructure analyses underestimate the costs of unforeseeable events for freight transport

The consequence of the five effects presented above is that the cost of events for freight transport on critical infrastructure are underestimated if the analysis focusses exclusively on the cost relating to specific trucks and freight that are delayed on the road by the event. In analyses of infrastructure in Denmark costs are currently only calculated for the trucks that are directly delayed in the event and the costs are based on the duration of the event. It must therefore be concluded that costs that arise for freight transport as a result of events on critical infrastructure are underestimated in Danish infrastructure analyses at present. Thus, current cost-benefit analyses of new infrastructure projects do not give a full picture of the economic consequences of these projects for freight transport.

In relation to the calculations around a 3rd Limfjord connection, this means that if a 3rd Limfjord connection minimizes the delays caused by events in the current Limfjord Tunnel, as the new connection will be able to carry the traffic, if the Limjord Tunnel is blocked due to accidents and vice versa, then the new connections will result in a cost saving for freight transport that is not included in the current cost-benefit analysis for a 3rd Limfjord connection.

5 Conclusion

The objective of this research project has been to analyse the consequences of delays caused by unforeseeable events, such as accidents, snowstorms and floods, for freight transport on critical infrastructure. There is both a scientific need for studies illuminating these consequences in detail, as discussed in chapter 2, as well as a practical need in Denmark, as the introduction in chapter 1 showed.

Critical infrastructure is defined as infrastructure where no alternative infrastructure exists, which can carry the traffic from the critical infrastructure in case of events blocking the critical infrastructure without significant congestion and delays. An example of such infrastructure is the Limfjord Tunnel in Aalborg, and therefore this was chosen as the case to illuminate the dynamics in chapter 3. A case study was therefore conducted of five logistics companies all operating trucks passing the Limfjord Tunnel. The results are:

1: The risk of experiencing delays causes logistics companies to invest before the events occur

The analysis shows that logistics companies are investing to minimize the risk of being delayed by unforeseeable events. Examples of this are: Investment in parking spaces and terminals in the larger Danish cities to minimize the need to drive in the morning rush hour traffic and thus the risk of being delayed if events occur in this traffic. Planning to drive early, and if possible, the day before so that the driver can sleep in the truck near to the delivery point. Adaption of vehicles for night-time delivery to minimize the need to drive in peak hour morning traffic, where the risks of events are high. Investments in extra trucks and trailers to be able to deal with the consequences of events. The analysis thus shows that events on critical infrastructure create costs for logistics companies even before they occur, as the companies invest to avoid driving in the morning and evening rush hours. This is where the risk of events such as traffic accidents is high, and the potential delays due to events are also most serious due to the amount of traffic. Further research is needed to analyse the size of these investments and thus the costs associated with this effect.

2: Delays can spread geographically downstream in the logistics operation to trucks and freight, which was not near the event

When a truck arrives late to a terminal due to an event then it is not only the truck, that arrives late, that will depart late. As the sorting operation in the terminal is delayed, the delay typically expands in scope to include several departing trucks. This may in turn generate delays at other terminals downstream in the operation, and thus the delay can spread downstream in the logistics operation to include freight and trucks that was not even near the road where the event happened, and the delays can survive in the terminal operations for days. This is a highly significant result, which has not been covered in the existing literature on value of time and value of reliability for freight transport. The implications of this, is that the impact of events is currently underestimated as these are calculated only in relation to the trucks and freight that are delayed on the road by the given event. Further research is needed to identify the average spread of delays to other trucks and freight downstream in the logistics operations so that it can be established how underestimated the delays are today.

3: Delays can increase in time downstream in logistics operations

The analysis shows that the timewise length of a delay can grow downstream in the logistics operation. It is in other words not necessarily equal to the amount of time the truck is delayed by the event on the road. The reason for this is primarily driving-resting-time regulation, i.e. drivers running out of driving time as routs are planned to utilize available driving time optimally and unforeseen delays therefore causes drivers to become stranded. Dependencies on for example ferries, and missed connections, can also increase the delay. This also a highly significant result, which have not been covered in the existing literature on value of time and value of reliability for freight transport. The implication is that current analysis of costs of events are underestimated as these calculations rely on the time the event takes on the road. The next step needed in research in this direction is to determine the relationship between the time the event takes on the road, and the delay generated downstream in the logistics operations as a consequence of this delay. When this relationship has been established, it will be possible to make more precise estimates of the costs associated with events.

4: Trucks on adjacent roads to the critical infrastructure can also be delayed

The analysis shows that when the Limfjord Tunnel is blocked due to an event, then traffic seeks towards the center of Aalborg and the Limfjord Bridge, but due to the limited capacity of this connection the result is typically widespread congestion and delays in Aalborg city center. This delays trucks operating in Aalborg south of the fjord, trucks which are not passing the Limfjord Tunnel on their trips.

This is also a highly significant result, which has not been covered in the existing literature on value of time and value of reliability for freight transport. The implication is that current analysis of costs of events are underestimated as these calculations only includes the trucks on the road where the event occurs. Future research is needed to analyse the extent of this issue in relation to events on critical infrastructure.

The Schulstad case further showed that the planning and restrictions on the road network around the critical infrastructure can push more trucks into rush hour traffic and thus worsen the costs of freight transport in the event of delays. Schulstad delivers at night in several Danish cities to avoid driving during the morning rush hour, and thus minimize the risk of being caught in a traffic accident, but due to Aalborg Municipality not allowing night delivery to the same extent as some other Danish cities, Schulstad has to drive during the morning rush hour in the Limfjord tunnel to deliver on the morning before the shops open in Aalborg.

5: Significantly more research is needed before it is possible to quantify the costs of events for logistics operations on critical infrastructure

The analysis shows that significant research is needed before the costs of events can be quantified. It makes no sense to quantify the costs of delays caused by events at this current stage, because the analysis has shown clearly that we do not know how much freight that is actually impacted by an event. Due to the effect's downstream in the logistics operations presented above, it is clear that we cannot use the number of trucks or amount of freight waiting in a queue by a given accident as

a measure of how many trucks and how much freight that is delayed by this accident. It is necessary to include the trucks and freight delayed downstream. Future research therefore needs to explore quantitatively how delays grow in time and spreads geographically to trucks and freight downstream in the logistics operations. Research is also needed to quantify to which extent trucks and freight on adjacent roads are delayed as a result of events. When these issues are quantified then it becomes possible to estimate the real number of trucks and amount of freight being delayed in the logistics operations by events. And when we can do that, we can start to look at the costs associated with these delays. Besides this, it is as mentioned also necessary to investigate quantitatively how much logistics companies invest to avoid events.

Looking at the costs of late delivery for logistics companies the analysis shows that it is necessary for future research to look at the demands and costs associated with delivery within specific industries as the study shows that significant differences exist between industries. Finally, another significant research lays ahead in establishing the costs of delays for the receivers of the freight. This means a focus on costs associated with safety stock and the costs of production stops if safety stock is depleted due to late delivery in different industries.

6: Danish infrastructure analyses underestimates the costs of unforeseeable events for freight transport

The consequence of the effects presented above is that the cost of events for freight transport on critical infrastructure are underestimated if the analysis focusses exclusively on the cost relating to the specific trucks and freight that are delayed on the road by the event. In analyses of infrastructure in Denmark cost is currently only calculated for the trucks that are directly delayed in the event and the costs are based on the duration of the event. It must therefore be concluded that the costs that arise for freight transport as a result of events on critical infrastructure are underestimated in Danish infrastructure analyses at present. Thus, current cost-benefit analyses of new infrastructure projects do not give a full picture of the economic consequences of these projects for freight transport.

In relation to the calculations around a 3rd Limfjord connection, this means that if a 3rd Limfjord connection minimizes the delays caused by events in the current Limfjord Tunnel, as the new connection will be able to carry the traffic if the Limjord Tunnel is blocked due to accidents and vice versa, then the new connection will result in a cost saving for freight transport that is not included in the current cost-benefit analysis for a 3rd Limfjord connection.

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